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Proceedings of the National Workshop on Objectives and Indicators For Ecosystem-based Management

Sidney, British Columbia
27 February – 2 March 2001

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ABSTRACT

During 27 February – 2 March 2001, a workshop was sponsored by Fisheries and Oceans Canada (DFO) in Sidney, B.C. to identify ecosystem-level objectives, with associated indicators and reference points, that could be used in managing ocean activities. Participants included DFO scientists, fisheries managers, ocean managers, and habitat managers, as well as experts from other federal government departments, academia and other nations. Under the overarching objective of conservation of species and habitat, the workshop defined objectives related to biodiversity, productivity and the physical and chemical properties of the ecosystem. Under each of these, further nested components were defined, along with an 'unpacking' process to link these conceptual objectives to those suitable for operational management. For each nested component, a suite of biological properties or characteristics was developed that further described the objective. Example indicators and reference points were also developed by operational objective, although further work on these at both a national and regional level is required. Assessment frameworks that evaluated progress against all objectives simultaneously were discussed and their potential uses investigated. A major achievement of the workshop was development at a national level of the concepts and terms related to ecosystem-based management. Finally, the workshop developed a list of issues and proposed next steps, including recommendations for further research, that DFO would need to address to further the implementation of ecosystem-based management in Canada.

RÉSUMÉ

Le ministère des Pêches et des Océans (MPO) a organisé un atelier, du 27 février au 2 mars 2001 à Sidney (C.-B.), pour définir des objectifs axés sur l'écosystème, ainsi que les indicateurs et les points de référence connexes, susceptibles d'être utilisés dans la gestion des activités océaniques. Y participaient des scientifiques, des gestionnaires des pêches, des gestionnaires des océans et des gestionnaires de l'habitat du MPO, ainsi que des experts d'autres ministères du gouvernementaux fédéral, des milieux universitaires et d'autres pays. Cet atelier, qui avait pour grand objectif la conservation des espèces et de leur habitat, a permis de définir des objectifs en matière de biodiversité, de productivité et de propriétés physiques et chimiques de l'écosystème. Pour chacun de ces objectifs, on a également défini des éléments imbriqués liant ces objectifs conceptuels à ceux qui conviennent à la gestion opérationnelle, et pour chaque élément on a établi un ensemble de propriétés ou de caractéristiques précisant davantage l'objectif. Des exemples d'indicateurs et de points de référence ont aussi été élaborés pour les objectifs opérationnels, quoiqu'il faille encore y travailler à l'échelle nationale et à l'échelle régionale. On a discuté des cadres d'évaluation qui ont servi à apprécier les progrès accomplis par rapport à tous les objectifs simultanément, et de leurs usages possibles. Un des principaux résultats de l'atelier a été l'élaboration, à l'échelle nationale, des concepts et des termes liés à la gestion axée sur l'écosystème. Enfin, l'atelier a débouché sur une liste des questions à étudier et des prochaines étapes proposées, y compris des recommandations de recherche, sur lesquelles le MPO devrait se pencher pour faire avancer la mise en oeuvre de la gestion axée sur l'écosystème au Canada.

EXECUTIVE SUMMARY

The 1997 Canada *Oceans Act* heralded a new approach to management of Canada's marine and freshwater resources. Under the *Fisheries Act*, resource management has been species and population based, with the emphasis on commercially important species and fish habitat management. The *Oceans Act* now requires consideration of the impacts of all human activities on the respective ecosystem.

During 27 February – 2 March 2001, a workshop was sponsored by Fisheries and Oceans Canada (DFO) in Sidney, B.C. to identify ecosystem-level objectives, with associated indicators and reference points, that could be used in managing ocean activities. Participants included DFO scientists, fisheries managers, ocean managers, and habitat managers, as well as experts from other federal government departments, academia and other nations. The objective of the workshop was to identify ecosystem-level objectives, with associated indicators and reference points, which could be used in setting up and implementing management plans for ocean activities and ultimately integrated management plans for ocean areas.

An approach to construct objectives for Ecosystem-Based Management was developed. At the highest level, conceptual objectives are stated in general terms that are intended to be understandable to a broad audience. At this level, the objectives can be considered as policy statements by a government or organization. However, they lack the specificity to be operational. An operational objective is one that consists of a verb (e.g., maintain), a specific measurable biological property or indicator (e.g., biomass), and a reference point (e.g., 50,000 t), which allows an action statement for management (e.g., maintain biomass of a given forage species greater than 50,000 t). Therefore, the conceptual objective needs to be developed further into a more specific nested objective. If this next objective can be associated with a management action, then it is considered an operational objective. The process of refining conceptual objectives to successively more specific levels until operational objectives are defined is termed "unpacking".

Two, broad, overarching general goals for ecosystem-based management (EBM) were accepted:

- the sustainability of human usage of environmental resources and,
- the conservation of species and habitats, including those other ecosystem components that may not be utilized by humans.

Discussion at the workshop focused on objectives under the second, conservation, goal. Initial conceptual objectives relating to biodiversity, productivity and the physical and chemical properties of the ecosystem were developed:

1. to conserve enough components (ecosystems, species, populations, etc.) so as to maintain the natural resilience of the ecosystem
2. to conserve each component of the ecosystem so that it can play its historic role in the foodweb (i.e., not cause any component of the ecosystem to be altered to such an extent that it ceases to play its historical role in a higher order component)
3. to conserve the physical and chemical properties of the ecosystem

The first conceptual objective has the following nested components:

1. to maintain communities within bounds of natural variability
2. to maintain species within bounds of natural variability
3. to maintain populations within bounds of natural variability

Current activities in relation to endangered and threatened species would be addressed under the species component, which thus provides a link to national and international species at risk acts, accords and legislation.

The second conceptual objective relates to the productivity of the ecosystem, with nested components being:

1. to maintain primary production within historic bounds of natural variability
2. to maintain trophic structure so that individual species/stage can play their historical role in the foodweb
3. to maintain mean generation times of populations within bounds of natural variability

Current work under the Fisheries Act relates primarily to these components.

The third conservation objective is intended to safeguard the physical and chemical structures within which the ecosystem resides, with nested components being:

1. to conserve critical landscape and bottomscape features
2. to conserve water column properties
3. to conserve water quality
4. to conserve biota quality

Under each of these components, further objectives were defined, through the 'unpacking' process, to link these conceptual objectives to those suitable for operational management. For each final nested objective, a suite of biological properties or characteristics was developed that further described the objective. Example indicators and reference points were also developed for some of these objectives. It is expected that specific situations within particular ecosystems, while starting from the same set of conceptual objectives, may produce different operational objectives through the unpacking exercise.

Some proposed assessment frameworks that allowed evaluation of progress against several objectives simultaneously were discussed and their potential uses investigated. Participants came away with an appreciation of ongoing work related to the assessment of the health of aquatic ecosystems and indicator development. Many participants heard for the first time about the utility of integrative assessment frameworks such as the Index of Biological Integrity (IBI) and the Traffic Light Approach (TLA) and expressed interest in learning more; other participants, already active in this research field, made useful connections for their ongoing work. Participants felt that these frameworks had sufficient merit to warrant their comparison with other approaches in the development of pilot projects.

Ocean, fisheries and habitat manager gave perspectives on their changing roles, the greater complexity of their jobs, and their need for greater technical support. Management issues relating to ecosystem delineation, social and economic variables, client buy-in, and the need for practical tools were raised.

The workshop identified issues and recommended next steps, including recommendations for further research within DFO to address the implementation of ecosystem-based management in Canada.

Issues

- Science must be able to provide indicators and reference points at regionally relevant scales.
- Social and economic objectives and indicators need to be addressed in concert with the biological ones also being considered.
- There is a need for clearly stated objectives, indicators and reference points in ecosystem-based management plans that are understandable by all stakeholders. The objectives and indicators that are utilized should be scientifically defensible, practical and pragmatic, repeatable, cost effective, transparent and relevant to operational staff for planning and project review.
- Further work on integrative assessment approaches is required, as there was little consensus at this time on the value of ecosystem-level indicators, i.e., is an overall indicator of MEQ, e.g. an IBI index value, interpretable or useful?
- Funding opportunities within DFO for terms longer than the existing 2-3 year maximum windows need to be created to address ecosystem-based management research
- It is critical that effective dialogue on ecosystem-based management be maintained both nationally and internationally so as to learn from each other and thus increase the chances of successful implementation.
- There is a need to involve stakeholders in the development of an ecosystem-based management process as soon as possible.
- The concepts and approaches discussed in the workshop can provide the link among DFO's Ocean Sector's Integrated Management (IM) initiative, Fisheries Sector's Objectives Based Fisheries Management (OBFM) initiative and the pending Species At Risk Act (SARA).
- It is important to develop a common understanding of terminology, as its absence slows progress in EBM.

Next Steps

- There is an immediate need to develop objectives for those dimensions of sustainability not covered at this workshop (social, economic, and cultural). This could be done through a workshop similar to the current one and involving the appropriate experts.
- There is a need for further reflection on the conceptual objectives discussed in the workshop, and on the operational objectives developed from these, as DFO moves toward application of an objectives-based approach to ocean management.
- The performance and sensitivity of integrative assessment approaches discussed at the workshop (IBI, TLA), as well as possibly others, should be evaluated at a number of locations across the country.
- There is a continued need for research to define the characteristics, indicators and reference points related to each objective, including consideration of their practicality, the extent to

which measurements can separate real change from background variability, cost of measurement, etc.

- The population dynamics of representative species of functional groups need to be further studied and appropriately characterised.
- Species inventories need to be compiled, i.e. what species are present and who can be tasked to evaluate this.
- Habitat issues such as the identification of critical (obligate) and facultative (important, but not always utilized) habitats and how do amount and spatial pattern of these habitats vary with the numbers of species, sizes of populations, etc., need to be addressed. Senior managers should consider forming a national study group on approaches to addressing habitat issues.
- Regional field studies to evaluate or 'road test' application of the concepts and approaches discussed at the workshop need to be funded and initiated soon. This could be part of current IM and OBFM initiatives.
- Regional consultative mechanisms for implementing agreed-to operational objectives need to be established.
- Consideration should be given for a second national workshop in 12-18 months to evaluate achievements and further conceptual progress in defining objectives, establishing priorities and identifying indicators.
- Consideration should be given to forming a national working group on ecosystem-based management indicators and reference points that would co-ordinate further national development and link this process to existing international initiatives (e.g., ICES, SCOR, etc).
- The findings of the workshop need to be quickly communicated to other regional science and management staff that could not attend the workshop, so that all relevant players are kept informed. Overall, DFO needs to think creatively about communicating this information; there should be strategic planning regarding the development and distribution of key messages.

INTRODUCTION

The 1997 Canada *Oceans Act* heralded a new approach to management of Canada's marine and freshwater resources. Under the *Fisheries Act*, resource management has been species and population based, with the emphasis on commercially important species and fish habitat management. While fishery management plans will continue to stress and be based on the status of target species, the *Oceans Act* has changed the legislative basis for management and requires consideration of the impacts of all human activities on the respective ecosystem. Even before the advent of the *Oceans Act*, the Department of Fisheries and Oceans (DFO) was active in addressing ecosystem-scale issues e.g. Hibernia, the PEI Fixed Link, and habitat policy issues. However, new impetus to an ecosystem approach to management was provided by the *Oceans Act* and since 1997, there have been a number of regional initiatives supporting this approach. For example, late in 1997, the Pacific Region organized a workshop on ecosystem delineation (Levings et al. 1998). In 1998, a pilot project was established in the Maritime Region to facilitate ecosystem-based management (EBM) on the Eastern Scotian Shelf, the scientific requirements of which were discussed at an Eastern Scotian Shelf Integrated Management (ESSIM) workshop in June 2000 (O'Boyle, 2000). Similarly, the Pacific Region joined the province of BC in initiating the Central Coast Land and Coastal Resource Management Plan (CCLCRMP) process, in another integrated management thrust.

As highlighted by these projects, planning requires that clear objectives are set, and for ecosystem-based planning, that ecosystem-level objectives are established. Under such an objectives-based framework for ocean management, all industries / activities within an area would accept and work within a framework of common objectives to conserve Canada's ecosystems. In June 2000, DFO's National Policy Committee (NPC) considered a framework for setting ecosystem objectives for integrated fisheries and oceans management. This framework proposed that a suite of objectives, indicators and associated reference points be developed for the maintenance of biodiversity, productivity and water quality within ecosystems of concern. Specifically, the framework proposed that human activities should be managed so as to maintain within acceptable bounds:

- The diversity of ecosystem types
- Species diversity
- Genetic variability within species
- Productivity of directly-impacted species
- Productivity of ecologically-dependent species
- Ecosystem structure and function

In subsequent discussions, an additional class of objectives related to water quality was identified.

The framework also proposed a means for operationalising a precautionary approach to ecosystem-based management, and noted the importance of defining ecosystem management areas. While examples of the indicators and reference points were considered, this was for discussion purposes as it was intended that these would be site and industry specific.

At the request of the NPC, a Working Group on Ecosystem Objectives (WGEO) was struck by DFO's Oceans and Science sectors to develop an operational framework for ecosystem – based management. At its initial meeting (October 2000), the WGEO recommended that a workshop be held to define the ecosystem features to be conserved, and the indicator framework to be used. Participants were to include DFO scientists, fisheries managers, ocean managers, and habitat managers, as well as experts from other federal government departments and nations. The objective of the workshop was:

> **to identify ecosystem-level objectives, with associated indicators and reference points, which could be used in setting up and implementing management plans for ocean activities and ultimately integrated management plans for ocean areas.**

The WGEO, in late 2000, struck a steering committee composed of a cross section of scientists from DFO (Appendix 1). The steering committee drafted a terms of reference and tasks for the workshop (Appendix 2) that was approved by the WGEO.

The workshop agenda (Appendix 3) was a combination of solicited working papers on specific topics with breakout groups and plenary discussion. The first day was devoted to an examination of ecosystem-level objectives more generally while the second day focused on lessons learned from areas inside and outside of Canada. The third day examined some proposed assessment frameworks, in which progress against several objectives can simultaneously be evaluated. The last day was devoted to discussion on the main recommendations of the workshop. The abstracts (by the presenter), presentation highlights and subsequent discussion (by the rapporteurs), as well as the discussion by the breakout groups and in plenary are provided in Appendix 4. The list of participants is given in Appendix 5 and the presenter biographies in Appendix 6.

The Executive Summary and Sections in the body of these Proceedings were drafted by the workshop steering committee subsequent to the workshop, based on Appendix 4 and feedback from the participants. They provide the main findings of the workshop. The first section presents a process of objective setting that allows linkage of conceptual with operational objectives. The second section provides examples of possible operational objectives related to the conceptual objectives discussed at the workshop. This is followed by an examination of each of the objectives identified, including nested objectives, characteristics, indicators and reference points. The next section on assessment approaches presents concepts and ideas on how progress against a suite of objectives can be measured.

During the workshop, selected fisheries, ocean and habitat managers were asked for their viewpoints on the workshop and on the needs of ecosystem-based management. These comments are summarised in the Manager's Perspectives section. The last two sections of the Proceedings present key issues raised and suggested next steps to be taken by DFO in implementing ecosystem-based management in Canada.

Finally, from the discussions held at the workshop, it was evident that agreement on terminology was essential to progress. The terms used at the workshop are given in Appendix 7. Finally, acronyms are given in Appendix 8.

SECTION 1: AN APPROACH TO SETTING ECOSYSTEM-BASED MANAGEMENT OBJECTIVES, INDICATORS AND REFERENCE POINTS

The workshop concluded that a sequential approach to developing operational objectives from conceptual ones was required. As a first step, conceptual objectives are stated in general terms that are intended to be understandable to a broad audience. Policy statements by a government or organization, for instance, can be considered conceptual objectives. However, given that they are broad statements, there is a danger that they will be interpreted differently by different people. In addition, they lack the specificity to be operational, i.e. a particular management action is based upon the degree of divergence of a measurable indicator from a reference point. It is thus necessary to develop the conceptual objective further. If this more specific objective can be associated with a management action, then it would be considered an operational objective. Otherwise, it would still be considered conceptual and require further development of specificity until it can be considered operational. This process of 'unpacking' is undertaken for all the conceptual objectives discussed at the workshop to make them operational and thus useful to management.

What We Desire			*What We Can Measure*
Conceptual Objectives		**Operational Objective**	**Indicators**
Objective ↳ objective ↳…	Maintain Productivity ↳Trophic Transfers ↳Forage Species ↳Target Escapement ↳(Maintain) Biomass	Consists of a Verb, Indicator and Reference Point e.g., Maintain Biomass > 50,000 t	Indicator

Figure 1: The link between qualitative, conceptual objectives and quantitative, operational objectives

An example of this process is given in Figure 1. Here, the maintenance of productivity is the conceptual objective that we wish to achieve. This can be stated more specifically as maintaining trophic transfers and interactions within the foodweb. While this restatement is a more tractable concept than maintenance of productivity, it is still far from what we could deal with practically. Therefore, the concept of 'trophic transfers' is further unpacked. This could produce a more specific statement on the maintenance of forage species, and then, in turn, of target escapement. We would finally reach a point that some characteristic of the ecosystem could be associated with a particular measure or indicator. At this point, one can consider developing the operational objective. The workshop considered that an operational objective consists of a verb (e.g., maintain), a specific measured indicator (e.g., biomass), and a reference point (e.g., 50,000 t), thus allowing an action statement for management (e.g., maintain biomass of a given forage species greater than 50,000 t biomass).

The term 'characteristic' used above was chosen carefully. It specifies some biological property of the ecosystem, separate from our measurement of it (although it should be measurable). For instance, spawning stock biomass might be the characteristic of interest. We don't necessarily measure spawning stock biomass directly. We do this through an indicator. For example, for the characteristic, spawning stock biomass, the indicator might be age-five weight per haul from a survey or the biomass output from a population analysis. In some cases, more than one indicator may be associated with a characteristic, requiring some summarisation of the indicators for that characteristic, perhaps through a modeling exercise. The value of defining characteristics relevant to each objective is that they both further describe the biological processes associated with the objective and guide choice of the appropriate indicators and reference points.

The term 'reference point' is a particular value of an indicator. Picking the reference point is a technical task once the indicator is chosen, albeit an important one critical for management purposes. It is the deviance of the indicator from the reference point that determines the management action.

There are a number of advantages of the nested, sequential, objective structure. First, within any one branch of the sequence, the process of 'unpacking' objectives creates the link between the qualitative, conceptual, objectives and the quantitative, operational ones used to guide management decision-making. Second, the relationship of one branch of the decision tree to another is clearly defined. It is thus possible to evaluate progress against objectives for each branch of the tree separately. Priorities could be set on the relative importance of achieving different objectives on different branches. It should be noted that progress can only be measured at the lowest operational level. Every level above that is not in the currency of something specifically measurable, so by definition one cannot "measure" progress at the higher levels. Lastly, a nested sequence facilitates communication within the management system. At the highest level, the objectives are stated in terms so that a broad understanding can be obtained by managers, scientists and stakeholders. This communication function is particularly important in ecosystem – based management, where a common set of objectives is being utilized across a number of sectors of society. As one proceeds through the sequence, technical considerations become more prominent. Nevertheless, the link between the conceptual and operational objectives is explicit and transparent to everyone.

The objectives' framework provided by the NPC related to biodiversity, productivity and water quality, with possible objectives considered under biodiversity and productivity. However, these objectives were not developed through a consensus building exercise and did not benefit from the 'unpacking' process outlined above. The workshop therefore reconsidered the framework and developed a new set of conceptual objectives, which were then subjected to the unpacking process to illustrate how one can make the essential link to operational objectives. The results of this process are discussed in greater detail in the following sections.

SECTION 2: OBJECTIVES FOR ECOSYSTEM-BASED MANAGEMENT

On the first day of the workshop, it was noted that sustainable development is based on economic, environmental, societal and cultural dimensions (Garcia, S.M. and D. Staples, 2000). It was reiterated that the focus of discussion at the workshop was to be the environmental dimension. However, throughout the workshop, the importance of the other dimensions was highlighted, particularly by the managers. It was generally agreed that since humans are also part of the ecosystem, it is appropriate that their requirements be considered as well. While the expertise to discuss the other dimensions was not present at this workshop, the need for future workshops that did involve the appropriate experts was recognised.

There was consensus that ecosystem-based management has two, broad, overarching goals:

1. the sustainability of human usage of environmental resources and,
2. the conservation of species and habitats, including those other ecosystem components that may not be utilized directly by humans.

The economic and social/cultural dimensions would be considered under the first objective, neither of which, as stated above, was considered at this workshop. There was debate that the second objective, conservation, should include societal and cultural dimensions, as well as environmental ones. The majority opinion was to restrict the conservation objective to the environmental dimension. [1]

It was generally agreed that ecosystem structure and function has physical, chemical and biological dimensions, and thus the objectives under the overarching conservation objective should cover the same range of issues/dimensions. The majority of discussion at the workshop focused on the objectives nested under conservation.

The three conceptual objectives derived during the workshop that, taken together, are necessary and sufficient for conservation are:

- to conserve enough components (ecosystems, species, populations, etc.) so as to maintain the natural resilience of the ecosystem

- to conserve each component of the ecosystem so that it can play its historic role in the foodweb (i.e., not cause any component of the ecosystem to be altered to such an extent that it ceases to play its identified historical role in a higher order component)

- to conserve the physical and chemical properties of the ecosystem

These objectives are stated at the same level of generality as considered by the NPC. While there are similarities, there are a number of differences, particularly as the concepts are unpacked, as will now be shown.

The first conceptual objective relates to ecosystem biodiversity, the intent being to maintain the diversity of communities, species, and populations within the bounds of natural variability. This addresses Canada's obligation through the Jakarta Convention to conserve biological diversity and implies that no communities, species, or populations should be lost through human activities. Three components were stated under the biodiversity conceptual objective, these being

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[1] There are strong links between the development of ecosystem objectives and the vision of Marine Environmental Quality (MEQ), as espoused in the 1997 Canada Oceans Act. The concept of MEQ was presented at the workshop and the participants were comfortable with viewing MEQ as encompassing all aspects of ecosystem structure and function.

1. to maintain communities within bounds of natural variability
2. to maintain species within bounds of natural variability
3. to maintain populations within bounds of natural variability

Current activities in relation to endangered and threatened species would be addressed under the species component.

The second conceptual objective relates to the productivity of the ecosystem. Three components were stated:

1. to maintain primary production within historic bounds of natural variability
2. to maintain trophic structure so that individual species/stage can play their historical role in the foodweb
3. to maintain mean generation times of populations within bounds of natural variability

Thus while the biodiversity conceptual objective considers the structure of the ecosystem, this conceptual objective deals with its functioning. The first component under productivity relates to conservation of the base of the food web. The second component requires that human activities that impact one part of the food web not adversely impact another. The last component relates to the maintenance of the productivity of individual populations. Traditional fisheries management activities would address these components for target and non-target populations.

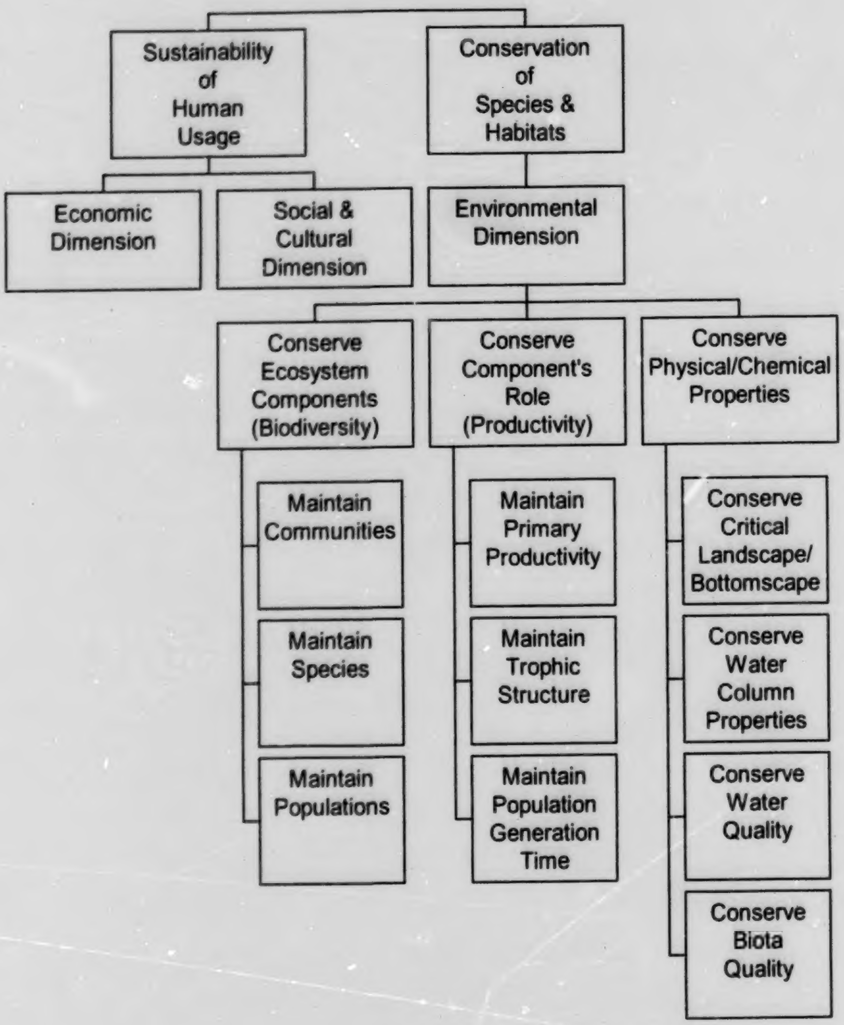
The third conceptual objective is intended to safeguard the physical and chemical structures within which the biological community resides. Much discussion revolved around the word 'habitat', as some participants saw this as including only the physical structure. Others saw habitat as defined within the Fisheries Act, i.e., 'spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes'. Others saw habitat as including biotic elements additional to this definition. No consensus could be reached on the use of the term 'habitat' and thus, its use was avoided in defining objectives (the term was used in other contexts and where found in this report should be considered to refer to the Fisheries Act definition). Four components were stated under this objective:

1. to conserve critical landscape and bottomscape features
2. to conserve water column properties
3. to conserve water quality
4. to conserve biota quality

Thus, by the nature of what are listed as a breakout of the 'habitat' objective, it can be seen we are proposing to treat "habitat" as the physical (including biogenic) structure of the habitat, not simply "where a specified animal lives".

The first component relates to the maintenance of physical features on the land (landscape and factors that influence the aquatic environment through run-off) and under the water (bottomscape). Note that bottomscape is meant to include corals, sponges, marine plants and other like organizms that, through their biological activity, create structural bottom features. The second component addresses issues related to movement of the water (i.e. tides, currents, etc). The third component deals with chemical condition of the water, while the last component deals with bio-accumulation of contaminants. This conservation objective substantially expands on the set provided by the NPC.

The set of objectives, as produced by the workshop, is given in Figure 2. As these objectives and their components are at the conceptual level, the workshop undertook the 'unpacking' exercise, described in the previous section, to develop operational objectives from these conceptual objectives. Sometimes the initial conceptual objective is specific enough that it can be operationalised in two or three steps. Other times, it might take more steps. Details as to how this may occur for each component are provided in the following sections. For each component, a set of ecosystem characteristics that are the target of that component were defined. This was useful in further clarifying the issues to be considered by that component. Next, indicators of that characteristic were discussed, along with associated reference points. Finally, an example operational objective was stated for each conceptual component, using the provided indicators and reference points. This unpacking exercise was conducted to illustrate the process of linking the conceptual and operational levels and should not be taken as producing the definitive suite of operational objectives for ecosystem-based management in Canada. It is expected that specific situations within particular ecosystems, while starting from the same set of conceptual objectives and components, will produce, through the unpacking exercise, different operational objectives. In addition, much research is required on the appropriate characteristics, indicators and reference points to use in association with particular components. Nevertheless, the objectives' sequence produced by the workshop can be used as a starting point for such exercises.



Sustainability of Human Usage
Conservation of Species & Habitats
Economic Dimension
Social & Cultural Dimension
Environmental Dimension
Conserve Ecosystem Components (Biodiversity)
Conserve Component's Role (Productivity)
Conserve Physical/Chemical Properties
Maintain Communities
Maintain Species
Maintain Populations
Maintain Primary Productivity
Maintain Trophic Structure
Maintain Population Generation Time
Conserve Critical Landscape/ Bottomscape
Conserve Water Column Properties
Conserve Water Quality
Conserve Biota Quality

Figure 2. Conservation Objectives for Ecosystem-Based Management in Canada

SECTION 3: OPERATIONALISATION OF THE CONCEPTUAL OBJECTIVES

To reiterate the previous section, the three conceptual conservation objectives (related to biodiversity, productivity and physical/chemical structure) derived during the workshop were

- to conserve enough components (ecosystems, species, populations, etc.) so as to maintain the natural resilience of the ecosystem
- to conserve each component of the ecosystem so that it can play its historic role in the foodweb (i.e. not cause any component of the ecosystem to be altered to such an extent that it ceases to play its historical role in a higher order component)

- to conserve the physical and chemical properties of the ecosystem

Tables 1 to 3 provide the components, characteristics, indicators, reference points (RPs), and operational objectives developed at the workshop to illustrate the process followed for each of these conceptual objectives. They are the result of cumulative discussions held over the course of this workshop. The main feature is the linkage of the conceptual objective on the left of each table with the operational objective on the right. Note that while the components and characteristics are reasonably well established, the associated indicators and reference points are only examples. Further research on many of these is required.

The tables make reference to "undisturbed" situations. These may often be suggested as appropriate benchmarks, but this may not always, or even often, be really the right benchmarks. We have no such benchmarks for many systems, and for ones where we do, the "undisturbed" areas may have been atypical from the beginning (otherwise we would have used or altered them too). Moreover, according to most theory, some moderate disturbance may increase many properties (diversity, productivity, etc) in ways that may be desirable from some conservation perspectives.

Table 1. Components, Characteristics, Indicators, Reference Points (RP) and Operational Objectives related to Biodiversity.

Component	Characteristics	Indicators (Illustrative)	Reference Points (RP)	Operational Objective
1. Maintain communities within bounds of natural variability	1. Trophic level balance	• Slope of Size spectra • Fishery is balanced Index (FIB) • Effective number of species within trophic level • Abundance of keystone species	Now unknown – possibly based on undisturbed system	Maintain trophic level balance relative to the RP, e.g. maintain size spectrum, FIB, number of species within trophic levels, etc., including a specified risk tolerance and desired value for the indicator
	2. Habitat complexity	• Numbers of identified communities (assemblage analysis) • Fragmentation (spatial pattern) of communities Index (ratio of abundance in disturbed/undisturbed areas)	Now unknown – possibly based on undisturbed system	Maintain habitat complexity relative to some RP, perhaps relative to existing or undisturbed situation
	3. Rare and sensitive habitats (Communities at Risk)	• Ratio of area of habitats that are protected to those unprotected	Now unknown	Maintain rare and sensitive habitats to some RP; e.g. relative to existing or undisturbed habitats
	4. Exotic species	• Number of exotic species	Numbers of exotic species near zero	Keep numbers of exotic species < RP
2. Maintain species within bounds of natural variability	1. Numbers of species	• Numbers of species in a location	Possibly based on undisturbed situations	Maintain numbers of species > some minimum RP

Component	Characteristics	Indicators (Illustrative)	Reference Points (RP)	Operational Objective
	2. Species at risk	• Many tools developed: - abundance - size structure - organism condition - growth rate	Population abundance of species before becoming "at risk"	Rebuild species at risk above reference points within a specified time frame
	3. Evolutionary Significant Units (ESU)	• Numbers of breeding individuals in the ESU	Reference levels perhaps based on existing or undisturbed situations relative to results of a population viability analysis	Maintain ESUs within species
3. Maintain populations within bounds of natural variability	1. Structure among populations	• Metapopulation structure • Presence/absence where they were before • Area of available habitats occupied	Reference levels relevant to each indicator, e.g. percent of available habitats occupied	Maintain an appropriate structure among populations e.g. at existing or undisturbed levels)
	2. Structure within populations	• Population size (N) • Presence/absence where they were before • Area of available habitats occupied • Effective population size (N_e) • Sex ratio • Age structure	Reference levels relevant to each indicator, e.g. population size, sex ratio, age structure, etc.	Maintain appropriate structure within populations relative to population viability analyses
	3. Populations at risk	• Numbers of populations defined to be at risk	Not examined	Rebuild populations at risk in a specified time frame
	4. Genetic diversity among populations	• Census population (N_c) • Molecular variance	Not examined	Maintain genetic diversity among populations to some

Component	Characteristics	Indicators (Illustrative)	Reference Points (RP)	Operational Objective
				specified level
	5. Genetic diversity within populations	• Allele frequencies (genetic variance) • Inbreeding coefficient	Not yet defined	Maintain genetic diversity within populations to some specified level

Table 2. Components, Characteristics, Indicators, Reference Points and Operational Objectives related to Productivity.

Component	Characteristics	Indicators (Illustrative)	Reference Points (RP)	Operational Objective
1. Maintain primary production within historic bounds of natural variability	1. Trophic status	• Nutrient concentrations • Index of Water clarity • Chlorophyll A concentration	Could be determined in some instances from undisturbed systems	Do not harvest species responsible for primary productivity
2. Maintain trophic structure so that individual species/stages can play their historic role in the foodweb (i.e., do not cause the trophic structure to become so altered that individual species/stage ceases to play its historical role in the foodweb)	1. Trophic complexity	• Number of trophic levels • Species/life stage size spectra • Diet composition and index of complexity • Niche width • Biomass • Spatial distribution	Could be determined in some instances from undisturbed systems	Maintain harvest of all species at a specified trophic level at a specified small percent of the estimated biomass.
	2. Habitat availability	• Areas of pelagic habitat • Area of benthic habitat • Area of inshore habitat • Nursery areas • Spawning areas • Area of Migration pathways	Should be determinable in most cases	"No net loss" policy applies here
	3. Predator-prey relationships	• Measure of Food web complexity • Abundance of Alternate prey • Predator induced mortality rates on prey populations • Biomass of key dependent predators	Prey species proportions	Maintain opportunities for historical predator-prey patterns

Component	Characteristics	Indicators (Illustrative)	Reference Points (RP)	Operational Objective
3. Maintain mean generation times of populations within bounds of natural variability	1. Longevity	• Life table structure • Survivorship curves • Mortality rate	Not examined	Maintain mean generation times
	2. Life history strategy	• Changes in reproductive parameters (age of maturity, time of breeding, etc. • Lifetime reproductive success rates (early vs. late maturation schedules)	Determinable by examination of species life-histories	Maintain mean generation times at historical levels
	3. Reproductive potential	• Fecundity • Early-life history survival rate • Spawning Biomass from population model	70% of virgin biomass	Maintain spawning biomass at 70% of virgin level
	4. Fishing Mortality	• Fishing Mortality from population model	F0.1, F med, F rep (there are a number of RPs available)	maintain fishing mortality at or below RP.

Table 3. Components, Characteristics, Indicators, Reference Points and Operational Objectives related to Physical and Chemical Properties.

Component	Characteristics	Indicators (Illustrative)	Reference Points (RP)	Operational Objective
1. Conserve critical landscape & bottomscape features	1. Coastal landscape complexity/ heterogeneity	• % coastline altered by human structures	Not Examined	Not Examined
	2. Terrestrial/ watershed inputs	• Volume of Runoff • Effective impervious area • % area under agriculture • % area logged • area of saltmarsh • area of wetlands	Not Examined	Not Examined
	3. Physiography/ morphology/ benthic	• Area of physical disturbance by trawling, dredging, mining	No benthic disturbance in critical habitats X% disturbance in other areas	Reduce physical disturbance of benthic areas to Reference Point levels
	4. Geology/ source materials (Sediments (sources/ conduits/ sinks)	• Grain size • areal distribution of grain size • TOC	Not Examined	Not Examined
	5. Biogenic structure	• % loss from natural for saltmarsh, corals, eelgrass	No loss of critical habitats	Restore to natural levels

Component	Characteristics	Indicators (Illustrative)	Reference Points (RP)	Operational Objective
2. Conserve Water Column Properties	1. Ice cover distribution 2. Tides, waves, fetch, currents 3. Fronts, gyres 4. Stratification 5. Temporal Changes 6. Freshwater inputs 7. Suspended solids	• Area & thickness of land-fast ice relative to baseline • Snow cover • TSS • Turbidity	Average conditions	Sustain historic levels
3. Conserve water quality	1. Chemical conditions 2. nutrients 3. contaminants 4. dissolved gases	• Concentration in media • End-of-pipe concentration	Concentration standard	No harmful residues as set by standard
5. Conserve biota quality	1. Contaminant loads 2. Bioaccumulation 3. Health of animals	• Tissue residues • Whole organism response (e.g. index based on behaviour) • cellular response (lethal, sublethal • Community response (e.g. indicator species)	Standards (e.g. Hg, D/F)	Don't exceed standards

SECTION 4: ASSESSMENT FRAMEWORKS

One of the objectives of the Ecosystem Objectives Workshop was to review the strengths, weaknesses and other issues of assessment approaches or frameworks that consider the status of sets of indicators pertinent to objectives in ecosystem-based management.

Various approaches to categorising and describing indicators are available. Two examples are the Index of Biotic Integrity (IBI) approach used in habitat-related issues and the Traffic Light Approach (TLA) used in fisheries situations.

IBI and TLA are certainly not the only indicator frameworks available. For example, Brian Smiley (DFO – Pacific Region) described at this workshop an indicator toolbox developed by DFO - Pacific Region that provides checklists of requirements and selection of indicators for monitoring, once particular objectives have been set. Similarly, Jean Munro (DFO – Laurentian Region) presented a "major issues x major ecosystem properties" approach for selecting indicators, illustrated with a case study on the fishery issue in the *Mya-Macoma* benthic community. However, for the purposes of this workshop, the IBI and TLA received special scrutiny as examples of assessment frameworks for ecosystem-based management that might be adopted nationally. These frameworks and discussion of their relative merits will be presented below. It is helpful to first list a few general impressions from this part of the workshop.

First, due to time constraints, none of the frameworks was presented in sufficient detail to be well understood by workshop participants. It was not the right setting for a technical review because of the limited time available, large group, and absence of computing facilities to do the necessary testing of alternatives. Nevertheless, the workshop served as a useful forum to consider the challenges in utilising these frameworks. Consequently, conclusions about the merit of pursuing any one of them must be regarded as tentative.

Second, participants came to the table with very different understandings of the questions to be addressed by assessment frameworks. At times, this resulted in discussions of how to apply particular, intriguing new tools rather than how we might address identified requirements for assessment and monitoring. Perceptions of the role of frameworks fell into two camps - one top-down and the other bottom-up. The top-down camp was interested in the questions: How healthy is the ecosystem relative to its potential, is it getting better or worse, and why? The bottom-up camp began from the starting point that indicators and reference points must be tied to particular activities and management objectives. For example, if harvest of wild shellfish were a management issue for a particular IM group, then area closures due to faecal coliform counts might be an appropriate indicator of the success of their management plan. The questions addressed by the top-down, i.e. "property based", and bottom-up, i.e. "threat- or use-based", approaches are related but failure by some to appreciate the utility of the two different perspectives sometimes impeded progress in discussions.

Finally, and again related to the relationship of assessment frameworks for ecosystem-based objectives, there was considerable discussion at the workshop about the organizational level at which indicators are helpful. The introduction of IBI, and at least certain applications of TLA, was predicated on the assumption that management at the ecosystem level requires indicators of ecosystem-level responses such as food web dynamics, species richness and evenness (diversity) and distribution of life histories. This raises the question "Does stewardship and conservation of ecosystem properties that can be measured require management objectives, indicators and reference points at the ecosystem level, or will the ecosystem be adequately protected by wise management of its component species?" More specifically for the present discussion, do we need assessment frameworks that describe the functioning or status of the ecosystem, such as IBI, or are species-specific indicators adequate? This question was not resolved at the workshop, except to note that indicators of ecosystem status and function had value at least as communication tools for management. It was noted, however, that this issue had been discussed at the November 22 – December 1, 1999 meeting of The Working Group on Ecosystem Effects of Fishing Activities (WGECO) of the ICES Advisory Committee on the Marine Environment, which concluded::

> "There has been considerable speculation as to the extent to which fishing may alter these emergent ecosystem properties (See ICES 1998 and earlier sections of this Report). It is also true that many press and popular articles have been highly emotive in their commentary on this issue. We have reviewed the **evidence** [bold in original] that has emerged since our last consideration and can find none which would cause us to revise our conclusions [that are in the 1998 report]. WGECO stresses that the need for some ecosystem reference points is real. At this time, WGECO believes that we are not in a position to recommend that ecosystem emergent property reference points are necessary, beyond the reference points which would assure sustainability and conservation of all species and habitats impacted by fishing. Neither are we prepared to confirm that single species, habitat, and genetic reference points alone are enough to ensure a precautionary approach to ecosystem management. Some study may yet provide compelling evidence that reference points for emergent properties of ecosystems are also required to ensure conservation of the ecosystem, but to this time none have." (pg. 78)
>
> "Emergent Properties: While not ruling out the need to continue to monitor developments in this area, WGECO finds no evidence that such ecosystem properties need, or even can be, subject to direct management objectives. However, WGECO acknowledges that, even if reference points for emergent properties are not warranted by present knowledge, many metrics of ecosystem properties, such as measures of diversity, can serve a valuable role in communicating with many clients of marine science…" (pg. 82)
> (report of November 22 – December 1 1999 meeting of ICES CM 2000/ACME:02. Ref.: ACFM +E).

Participants came away from the discussion with a much better appreciation of ongoing Canadian work related to assessing the health of aquatic ecosystems and indicator development. Many participants learned about the IBI and TLA for the first time and expressed interest in learning more; other participants, already active in this research field, made useful connections for their ongoing work. In general, participants felt that the assessment frameworks discussed had sufficient merit to warrant their comparison with other approaches in pilot projects (see recommendations below)

The Index of Biotic Integrity (IBI)

The Index of Biotic Integrity is a technique for assessing the relative health of an animal community living in a particular ecosystem. It pools information from a series of different biotic and abiotic indicators to arrive at an overall assessment of the degree to which the community has its requisite components (i.e., structure) and normal interrelationships among those components (i.e., function). IBI integrates information from the individual, population, community, zoogeographic and ecosystem levels. Selected indicators may include taxonomic diversity, tolerance vs. intolerance, trophic structure and measures of an organism's condition. Each indicator in impacted areas is evaluated against a pristine reference site. If the indicator is comparable to the reference site, it is awarded a score of 5, if somewhat compromised, a score of 3 and if greatly compromised, a score of 1. All indicator scores are then summed, without weighting, to produce an overall IBI. For example, an IBI composed of 12 indicators would score 60 if comparable in all attributes with the reference site, 12 if degraded in all respects, and a number between 12 and 60 would reflect intermediate biological integrity.

The perceived advantage of this integrative approach over individual indicator approaches is that, being broad-based, it is more likely to detect environmental degradation. For example, any given indicator species may be extremely sensitive to certain forms of environmental perturbation, but completely insensitive to others. Certain broadly used indices – such as diversity indices – may be insensitive to many impacts except extreme pollution stressors. Furthermore, IBI preserves for evaluation the data associated with the specific components. Therefore, in cases where environmental degradation is reflected in the overall IBI score, component indicators can be examined to begin the investigation of cause. It was suggested that Principal Component Analysis (PCA) and other multivariate statistical techniques were useful adjuncts for discriminating patterns in multivariate datasets, such as those generated for IBI. As well, IBI is conceptually simple, transportable, easy to teach and possibly relatively inexpensive. However, there are no rules for what is necessary and sufficient to include on the list of constituent indicators, and so IBI is as costly as the indicators incorporated. Its robustness (in the sense that it gives reliably low error rates in all contexts), has never been tested formally, although anecdotal evidence suggests both miss and false alarm rates can be high – especially miss rates. Its utility in management applications is also unknown but could be investigated through simulation exercises. Nevertheless, IBI is attractive as a communication tool for managers and as a monitoring tool that can be adopted by community groups.

IBI has been reported in over 200 peer-reviewed publications covering a variety of terrestrial and aquatic ecosystems. Several review articles are critical of its use in management contexts, though, and its appropriate application needs to be determined. Very few applications deal with marine ecosystems. However, Dr. J. Karr – IBI's developer and a participant at this workshop– sees no reason that it cannot be applied to marine ecosystems and has a graduate student presently working on a marine IBI in the coastal environment of Puget Sound. Canadian applications of IBI include research by faculty at Royal Roads University in Victoria, BC (Brian Smiley, DFO-IOS, pers. comm.) and applications of IBI in Pacific Rim National Park (Cliff Robinson, Parks Canada, Vancouver BC, pers. comm) and in the southern Gulf Islands (G. Jamieson, pers. comm.). PAPRICAN – a research organization for the Canadian pulp and paper industry – carried out a comparison of IBI and the sentinel fish survey required for the Pulp and

Paper Effluent Regulations – Environmental Effects Monitoring Program (PPER-EEM) in Québec. It is presently analyzing the results for publication. Greg Klassen (University of New Brunswick in St. John) is testing the sensitivity of IBI, relative to other approaches, in Kouchibouguac National Park, NB. In the freshwater environment, Dr. Ken Minns (DFO-Central and Arctic Region) has examined IBI applications in the Great Lakes for years.

Concerns about IBI articulated by participants included that it relies on comparisons with a relatively pristine or unaffected reference site that may be difficult to find within a particular geographic area. However, it was also noted that IBI could make comparisons against historical reference conditions if such were known. Secondly, IBIs must be developed for different biogeographies, rather than being broadly applicable. For example, the estuarine IBI developed for coastal waters of Massachusetts (Deegan et al. 1997) is not directly applicable to the relatively species-depauperate estuaries of the southern Gulf of St. Lawrence. Thirdly, concern was expressed over non-orthogonality of component indicators. The IBI specifically favours redundancy of highly intercorrelated indicators – potentially rendering it insensitive to certain changes and hypersensitive to others. A fourth concern expressed by some participants was the potential ambiguity of the overall IBI index. The IBI could arrive at the same overall assessment through different combinations of component indicators, which might be a concern for interpretation and utility by managers.

Traffic Light Approach (TLA)

Traffic Light Analysis is a data-based, rather than model-based, method for the integration and presentation of resource status information. To date it has been primarily used for presenting fisheries data. The approach was originally proposed (Caddy, 1999) for fish stock assessment in data-poor situations. It is so-named because indicators are assigned to one of three colours - green for good, yellow for intermediate, and red for bad. This direct conversion will cause a loss of precision. Other methods of conversion are under consideration, which retain more precision through the analysis. Regardless of technique, conversion has the advantage of recasting disparate data into a common currency for presentation or subsequent analysis.

In the case of reducing data to three colours, two cut-points are required which may be based on analysis (e.g., F0.1), history (xth percentile) or perhaps arbitrary criteria. The process of designating cut-points is critical to the TLA approach.

Multiple indicators are listed, each given equal weight, and are grouped into composites of related indicators for subsequent analysis. All indicators are shown and summaries are then presented which are either a weighted average of indicators or a model-based result from the composites. A key principle in TLA is transparency - all indicators, their values, and how they are subsequently grouped are presented. Yet, though all the component information is available, a clear summary is presented for the use of managers and as a communication tool. It was pointed out that the Fraser River estuary program has been using colour coding of habitat as a management scheme for a decade.

It has been proposed that weighting might be given to indicators reflecting ecological status such as mean trophic level. However, whether this is appropriate and how this might be evaluated is unclear. Such indicators are often mixed with a variety of indicators derived from single species evaluations that reflect the impact of ecosystem processes on those species, such as variations in natural mortality.

The method is still undergoing development and testing and it has been used in DFO stock assessments (e.g. Newfoundland shrimp and Maritimes groundfish). Interactive and web versions have been developed. TLA has been used in recent Maritimes Regional Advisory Process (RAP) meetings and a validation workshop, emphasising indicators and integration, is planned for the summer of 2001.

Next Step on Assessment Frameworks

A number of constructive suggestions were offered to move consideration of integrative assessment frameworks forward. First, there was consensus that the IBI and TLA approaches had sufficient merit to warrant a more thorough technical review. A specific suggestion was that an expert workshop be held in the fall of 2001 for the comparison of IBI and TLA with other indicator frameworks. A workshop or review panel of quantitatively skilled individuals not associated with any framework *a priori* that would review alternatives might be most appropriate, with a few proponents of each method there to explain and perform tests in response to directions from the panel. The outcome of this workshop would be recommendations for departmental research. This workshop might also produce specific recommendations on pilot projects for the testing of different assessment frameworks (see below).

Second, it was suggested that the relative sensitivities of integrative assessment frameworks to address particular objectives be examined with simulations using historical data such as those from the Atlantic trawling surveys. This exercise could also provide valuation of the data that is, one hopes, independent of the frameworks by indicating the costs of not carrying out monitoring. Simulation work could precede the initiation of pilot projects and/or be carried out as part of the pilot project exercise (see below).

Third, participants supported comparing integrative framework approaches in pilot sites - perhaps one on each coast for example. The timeframe envisaged for successful pilot projects is five years. Criteria for the selection of pilot sites might include:

- having an IM plan in place with objectives established (e.g., Gulf of St. Lawrence Integrated Management project, GOSLIM);
- MPA sites (e.g., Mactaquac Estuary, Bay of Fundy);
- identification of a major issue (e.g., Manicouagan Reservoir and River, Québec);
- completeness of data available for modeling/simulation as a first step (e.g., Georgia Basin, BC);
- presence of ongoing initiatives and external partners such as universities and Parks Canada for collaboration (e.g., Richibucto Environment and Resource Enhancement Project (REREP), Richibucto, NB).

Rather than simply adopting a single assessment framework, participants supported the approach being pursued by G. Klassen in Kouchibouguac Park - namely to collect data sufficient for constructing the IBI/TLA and also for carrying out other analyses and presentations of the data (e.g., AMOEBA, MDS, PCA, DELPHI, etc.) and then comparing the information generated by the different approaches. Questions to be addressed would include:

- does the IBI, TLA or similar approach generate useful information additional to that of its component indicators?
- is the integrative assessment approach more or less sensitive than other approaches in detecting environmental degradation, presupposing that the significant environmental events that good measures should be able to detect were identified before the testing, and independently of the method whose sensitivity is being tested?, and;
- can the IBI, TLA and other like procedures arrive at the same overall assessment through different combinations of component indicators, and if so, is this a concern for interpretation and utility by managers?

SECTION 5: MANAGERS' PERSPECTIVES

Although the managers who spoke at this workshop had very diverse program mandates and opinions, a number of similar themes were heard. Almost all of the managers noted that they (and their clients) have changing roles and a far more complex "world" to deal with, particularly in recent years. One of the ways to deal with this change / complexity is to have adequate technical support. The managers also provided advice to scientists regarding the establishment of ecosystem objectives. These themes are discussed in more detail below.

Changing Roles and Greater Complexity

The passage of the *Oceans Act* has formalised a mandate within DFO to take an ecosystem approach for management purposes. The traditional roles of the DFO manager (integrate resource use planning, project reviews, compliance monitoring, enforcement, education, etc.) now have an ecosystem overlay. Ecosystem objectives and indicators are now required at the planning table, rather than being an intuitive part of a DFO manager's thought processes. The goals of management planning are harmony among users of the marine environment and conservation of marine ecosystems.

Current management and management planning processes must now change to meet the goals of the *Oceans Act*, all within the limitations of the financial and human resources that managers have at their disposal. The move within DFO policy from "conservation" to "ecosystem management" represents a great challenge. It is worth noting that we are still struggling to define basic terms.

Attempts to implement ecosystem approaches are complicating already complex management issues. This can complicate the activities of some traditional DFO clients such as fishermen. Fisheries clients may have difficulty agreeing on a multispecies view for management, as fishers often focus on single species in their activities, although they may have a sophisticated understanding of the interactions between species and their habitats. Fishermen have had to adjust to decades of single species rules regarding harvest plans, in-season management applications, industry management boards, allocation and access issues, common property vs.

quasi property rights, etc. They must also now cope with endangered species, marine protected areas, oil and gas development, cables, bottom impacts, aquaculture, ocean dumping, etc. All of this represents constant change and if we are to be successful it will be because we can successfully manage change.

Ecosystem complexity is matched by complexity of stakeholder groups. Citizens, communities, industries, aboriginal groups, non-governmental organizations (NGOs), academics, municipalities, provincial representatives, and federal agencies - all vie for attention at the management table. This creates a governance mosaic of political, legal, regulatory, international, and local composition that sometimes may appear to work at cross-purposes.

The manager's reality is evolving – it is moving from single stock to multispecies fish management, from mostly fisheries users to multiple users (fishing, transportation, oil and gas, aquaculture, ecotourism, recreational boating, dumping, mining, etc.), and lastly moving from management by activity to Integrated Management.

Operationalising an ecosystem-based management framework can be achieved if it is comprehensive enough so that other agencies also fit within it, but our framework is not yet at that point.

The Need for Technical Support

Managers require technical and scientific support on ecosystem issues. The challenge for scientists is to continue studying and monitoring ecosystem complexity while translating this knowledge (and those results) to provide tools, albeit ones that will need regular monitoring as to their effectiveness and utility for at least the fist decade or so, for managers to use (i.e. good advice on developing ecosystem objectives and indicators). The tools need to be relatively simple, workable, explainable, sellable and efficient. Science will not be pre-empting the jurisdiction of managers, but in the early stages of EBM, each decision is going to be an experiment in management and the application of science. This process needs to be planned together, implemented together, and monitored together, to maximise the learning from each activity. The proven tools will come in about 20 years, when we know how to tell a screwdriver from a hammer (and what type of problem needs which) in an ecosystem management perspective.

The relationship between managers and scientists is a reciprocal one. Scientists need managers to buy into the ecosystem approach, to explain this approach to users and clients, to seek out allies and visionaries among these clients, and to define information requirements for scientists. Managers are required to help seek funding for science to support the ecosystem approach, and have a key role in posing informed requests for advice, in designing management measures that as informative as possible, and many other roles in support of science.

The push to develop indicators should not become an excuse to use a simplistic, potentially dangerous ecosystem model. Conversely, a manager cannot wait for years of monitoring to determine if harm is happening. Indicator development work is important, but shouldn't be used as an excuse for delaying corrective action when a problem has been shown to exist.

Technical support is required for a long-term perspective, as is a common language between clients, managers and scientists. Alliances and partnerships between managers and scientists must be formed outside of the confines of single species / single fishermen / single industry frameworks. It is important to ensure that we don't allow a "cultural" gap to form between managers and scientists.

A Management Approach to Developing Ecosystem Objectives

A number of managers at this workshop provided useful points for proceeding with a management approach to developing ecosystem objectives. Action is required on the following issues:

a) ecosystem delineation

In almost all instances, DFO managers work within carefully defined geographic boundaries. Nested ecosystem maps are useful within these boundaries. However, ecosystem map boundaries are often fuzzy and vary with management perspective. Issues of varying scale (community, industry, and biological) often preclude the development of fixed maps.

With these caveats in mind, DFO should perhaps not embark on major habitat mapping initiatives that use a habitat classification system that is only useful from a narrow range of perspectives or spatial scales. However, a mapping initiative based on physical and bio-structural features that can be recombined in many ways as needs change would be consistent with the need for nested definitions of ecosystems. However, it would be useful to have a common set of goals and objectives and indicators for a well-defined ecosystem so that progress can be assessed. Ecosystem maps could be built-up over time as management issues evolve for a particular area. The ecosystem boundaries could be corrected as we learn more about the system, as part of an iterative, ongoing process.

b) social and economic variables

Although DFO managers are usually not social scientists or economists by training, they frequently have to deal with those fields of study. DFO managers must make hard decisions on issues that are worth billions of dollars to the Canadian economy. As one manager put it, "the buck stops here"! That does not mean that social and economic variables should override a DFO manager's decision regarding ecosystem health, however. The best environmental decisions come from an awareness of the interrelationships between cultural, social, economic and ecosystem parameters, some of which are very difficult to quantify. This may be particularly important for managing non-consumptive use of marine environments (recreational opportunities, protected areas, etc.).

Social and economic indicators are important because they provide a context for biological indicators. Community involvement and buy in is also more likely with the inclusion of social and economic indicators. These indicators are also important if one considers that DFO is focused on managing people – not ecosystems.

c) client buy-in

We must consider associated client / management costs in operationalising a framework of ecosystem objectives and indicators. Why objectives are important needs to be communicated to DFO clients, and be properly justified.

Ecosystem-based management requires involvement and compliance by user groups who impact the ecosystem. Client buy-in is essential, otherwise the exercise will fail. Objectives have to be clear, measurable, with well-defined results or actions, and be understood and acceptable to ocean industries.

Communication is central to DFO/client relationships. A common language is required to enable the inclusion of stakeholders. It is important to be explicit about what is acceptable and unacceptable behaviour. A clear message and a toolbox for field use would be very helpful for managers who must explain ecosystem issues and the ecosystem approach to clients. Some of the messages will not be simple, though, and they should not so over-simplified that they are wrong, or permit challenges to issues that are not central to the concerns on which decisions hinge.

There is the need to influence major industrial players to accept an ecosystem view of management. DFO cannot force change, but can try to influence behaviour. The department should aim for incremental changes, and to phase in new strategies for ecosystem management.

The department is involved in public advisory processes – how should we connect this discussion to these processes? There is considerable pressure for greater departmental transparency (from the public) and clear, understandable, scientifically-based and workable indicators (from the government). Collaboration requires a degree of co-management, to the extent that co-management is a legislated requirement under land claims agreements in the north. A re-thinking of institutional structures and mechanisms is required to facilitate interaction with stakeholders (stewardship), empowerment (awareness raising, extension), and public education.

Ocean Managers face complex management issues (e.g. seabed uses, hydrocarbon extraction, etc.). They face a hierarchy of "visions" or issues, from international treaties to national concerns to local issues (e.g., DFO targets both offshore and inshore clients). There has been a tendency to let local community interests dominate. The problem, therefore, is how to link these interests into the larger national and international visions. The ecosystem based management approach may be hard to operationalise but it is important nonetheless in helping stakeholders to agree on a common vision.

Many coastal areas in Canada have recently been placed under a host of management plans and strategies that are all being adaptively implemented. In order to maintain the sanity of both clients and DFO managers, it would be helpful to develop common ecosystem objectives and indicators as these plans are implemented.

d) the need for practical tools

The managers at this workshop frequently spoke of the need for practical tools to solve their day-to-day problems. However, it must be recognised that ecosystem management is not going to solve the every-day problems of managers. It will be even more strategic than fisheries management and even further removed form daily problems of managers. It might "solve" one call by bringing more order to competing priorities, but by making a broader class of priorities legitimate, it will create many other new day to day problems for managers. The objectives and indicators that should be eventually followed are those that are practical and pragmatic, repeatable, cost-effective, and helpful for operational staff for planning and project review. Technical and science support staff must remember that decisions are made using a mix of science, local knowledge, experience, application of "policy", "gut instinct", and an ecosystem perspective. Managers need a short list of critical indicators that will attract clients to the table so that limits can be set. Clients must also have clear management rules that kick in when a particular critical point is reached, i.e., a dynamic feedback mechanism.

Since there are many differences between regions, a simple framework that is flexible enough to accommodate everyone is required. Most participants agreed that the message scientists give needn't be "simple", but rather it should be clear and understandable. It is important not to oversimplify, as the management of our oceans is by no means simple.

SECTION 6: KEY ISSUES

During the discussion, a number of issues surfaced that were considered key to the further development of Ecosystem-Based Management in Canada. These are summarised here according to the workshop's Terms of Reference.

Objectives, Indicators and Reference Points

- While there is a need to foster a common approach to ecosystem-based management nationally, Science must be able to provide indicators and reference points at regionally-relevant scales. On-going and new studies are required, but existing and new knowledge needs to be provided to managers in a format that they can use in decision-making processes. Reciprocally, the support of managers is required to help define information requirements and seek funding for Science to support development of an ecosystem approach to management.
- Social and economic objectives and indicators need to be addressed in concert with the biological ones also being considered. A healthy environment requires that data on economic, social and cultural, and environmental dimensions be provided in harmony with each other. Consideration of any individual element without appropriate consideration of the others is likely to stall the overall process of achieving the desired ecosystem-based management objectives.
- There is a need for practical tools to solve the day-to-day problems. There is a need for clearly stated objectives, indicators and reference points in ecosystem-based management plans, which are understandable by all stakeholders. The objectives and indicators that are

ultimately utilized should be scientifically defensible practical and pragmatic, repeatable, cost effective, transparent and relevant to operational staff for planning and project review.

Assessment Approaches

- There was good discussion at the workshop on potential assessment approaches that could summarise information at different scales of the ecosystem. Further work on these approaches is required, as there was little consensus on the value of ecosystem-level indicators.

Research and Management Directions for the Future

- There is little directed research underway by DFO Science today that is focused on addressing ecosystem-based management issues, and particularly the evaluation and testing of indicators as to their utility inecosystem-based management. Funding opportunities within DFO for terms longer than the existing 2-3 year maximum windows need to be created to address this deficiency.

Foster Common Understanding of Ecosystem-Based Management

- There has been considerable recent thinking and debate on ecosystem-based management nationally and internationally but little practical experience to date. It is critical that dialogue on ecosystem-based management be maintained both nationally and internationally so as to learn from each other and thus increase the chances of successful implementation.
- There is a need to involve stakeholders in the ecosystem-based management process. Associated client / management costs in effecting a framework of ecosystem objectives and indicators need to be determined. Objectives need to be effectively and appropriately justified to clients as to why they are important.
- The concepts and approaches discussed in the workshop can provide the link among DFO's Ocean Sector's Integrated Management (IM) initiative, Fisheries Sector's Objectives Based Fisheries Management (OBFM) initiative and the pending Species At Risk Act (SARA). For instance, inclusion of the objectives discussed at the workshop in OBFM plans might be an effective way of meeting IM requirements in fisheries.
- Terminology was an issue at the workshop, as the debate on "habitat" exemplified. It is important to develop a common understanding of terminology, as its absence slows progress onecosystem-based management.

SECTION 7: NEXT STEPS

Both during the breakout group and plenary discussions throughout the workshop, a number of 'next steps' became evident. These are summarized below, again according to the workshop's Terms of Reference, in no order of priority.

Objectives, Indicators and Reference Points

- There is a need to develop objectives for the dimensions of sustainability not covered at the workshop (social, economic, and cultural). This could be done through a workshop similar to the current one but involving the appropriate experts.
- There is a need for further reflection on the conceptual objectives defined here, and on the operational objectives developed from these, as DFO moves toward application of an objectives-based approach to ocean management

Assessment Approaches

- There should be an expert workshop in the fall of 2001 to technically review the assessment approaches discussed at this workshop, as well as others. The performance and sensitivity of these approaches might be initially done through exercises using existing and simulated data.
- Over the longer term, there should be a comparison of assessment approaches using pilot sites across Canada.

Research Directions for the Future

- The need for continued research to define the characteristics, indicators and reference points related to each objective was apparent, including consideration of their practicality, the extent to which measurements can separate real change form background variability, cost of measurement, etc.
- The population dynamics of representative species of functional groups need to be studied. This could involve the identification of "keystone" species, including determination of an objective and non-circular way of determining "sensitive" and "controlling" species.
- Species inventories need to be compiled, i.e. what species are present and who can be tasked to evaluate this?
- Questions related to habitat (as defined in the Fisheries Act) need to be addressed. What habitat is critical in the functional sense and the importance of amount and pattern in the structural sense? How does amount and spatial pattern of important habitats vary with the numbers of species, sizes of populations, etc.? It might be useful to form a national study group on approaches to habitat definition.

Management Directions for the Future

- It is important to 'road test' the concepts and approaches discussed at the workshop, perhaps as part of planned IM and OBFM initiatives. Only by initiating a nationally co-ordinated system of pilot studies will the challenges, opportunities and utility of different approaches be operationally evaluated. It was noted that the Antarctic case studies were deliberately selected to cover a range of conditions (from poorly to well understood components, small to large, etc.). However, there is also merit in maintaining some comparability among the pilots. Such exercises would need to include:
  1. A synthesis of all information already available, including data not traditionally reviewed (e.g., socio-economic),

2. Broad practical experience in actually compiling ecosystem-level data, and utilising these data in ecosystem function measurements to compare experiences from different situations,
3. Practical experience with regional 'unpacking' exercises to operationalise the conceptual objectives, and
4. An assessment of the costs of conducting the required ecosystem monitoring. Time series of data could be analyzed to measure the management consequences of having different levels of data to use.

Foster Common Understanding of Ecosystem-Based Management

- Regional consultative mechanisms for implementing the operational objectives need to be developed. Over the short term, regional meetings to consider both operational objectives and indicators on ecosystem issues and at appropriate scales are required. These would initiate a process, which is transparent to scientists, managers and clients, of establishing regional priorities and timelines. Efforts should as much as possible link these meetings to existing IM and MPA initiatives. The choice of operational objectives and indicators should involve as many parties as possible that are involved in decision making (communities, industry, non-governmental organizations, etc), to obtain agreement from as many sectors as possible. The objectives and indicators selected may come from a nationally developed list, or proposed by regional all-party committees, with opportunity for a scientific input.
- Consideration should be given to a second national workshop in 12-18 months time to evaluate achievements and further conceptual progress in defining objectives, establishing priorities and identifying indicators. Regional staff should have more time than allowed for in this workshop to prepare for the next workshop, both to ensure that the appropriate regional representatives can attend and to bring to the meeting regionally discussed perspectives.
- The workshop pointed to the international and national efforts on ecosystem-based management and the need for continued interaction among the practitioners to further its development. It might be useful to form a national working group on EBM indicators and reference points that would co-ordinate further national development. This group would also link to existing international initiatives (ICES, SCOR, etc).
- It is essential to communicate the findings of the workshop with regional science and management staff. Overall, DFO needs to think more creatively about communicating this information. There should be strategic planning regarding the development of key messages.

SECTION 8: CONCLUDING REMARKS

The workshop participants thoroughly discussed the objectives of the National Policy Committee and responded with another set of "high level" objectives embedded in a newly proposed EBM Framework. Along with the objectives, the workshop participants were successful in a few cases in applying an unpacking approach to move from conceptual ideas to illustrative operational objectives components, characteristics and indicators, which further illustrate the intent of the higher level, conceptual, objectives. The workshop participants also discussed promising methods that would allow monitoring of progress towards the objectives. Finally, the workshop brought together a diverse group of scientists, managers, policymakers, and regions to discuss the highly complex issue of ecosystem-based management. During the discussion, old definitions were clarified and new ones added. Overall, we believe the workshop achieved its stated objective and has improved awareness of ecosystem-based management in the DFO.

ACKNOWLEDGEMENTS

We acknowledge the efforts of the many individuals that made this workshop possible, particularly the speakers and participants. First, Howard Powles and Camille Mageau of the National Ecosystem Objectives Working Group had the vision to foster this workshop and seek national discussion on the complicated topic of objectives as a basis for ocean management. . Second, the workshop facilitators, Kristen Jordan and Colin Rankin, who faithfully recorded all the discussions and prepared the first draft of the Proceedings' appendices. Third, those participants who provided extensive review comments, notably Jake Rice and Howard Powles. And above all, a special thanks to Luanne Chew, who was instrumental in organizing the logistics of the workshop and pulling together an almost complete draft of the Proceedings. Her patience in dealing with such a diversity of very busy participants is commended.

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APPENDICES

APPENDIX 1. WORKSHOP STEERING COMMITTEE

Co-Chairs	Glen Jamieson (Pacific) / Bob O'Boyle (Maritimes)
National Headquarters	Herb Vandermeulen
Newfoundland	Robert Gregory
Maritimes	Joe Arbour
Maritimes-Gulf	Simon Courtenay
Laurentian	Jean Munro
Central & Arctic	Don Cobb
Pacific	Colin Levings, Ian Perry

APPENDIX 2. WORKSHOP TERMS OF REFERENCE

Background

The 1997 Canada *Oceans Act* heralded a new approach to management of Canada's marine and freshwater resources. Under the *Fisheries Act*, resource management has been species and population based, with the emphasis on commercially important species. The *Oceans Act* now requires consideration of the impacts of all human activities on the respective ecosystem. Since 1997, there have been a number of regional initiatives supporting the ecosystem approach. For example, a pilot project was established in the Maritime Region to facilitate ecosystem-based management on the Eastern Scotian Shelf, the scientific requirements of which were discussed at an ESSIM workshop in June 2000 (O'Boyle, 2000). Similarly, the Pacific Region joined the province of BC in initiating the CCLCRMP process, an IM thrust. And late in 1997, the Pacific Region organized a workshop on ecosystem delineation (Levings et al., 1998).

As highlighted by these projects, planning requires that clear objectives are set, and for ecosystem-based planning, ecosystem-level objectives are established. All industries / activities within an area would accept and work within a framework of common objectives to conserve Canada's ecosystems. In June 2000, DFO's NPC adopted a framework for setting ecosystem objectives for integrated fisheries and oceans management. This framework proposed a suite of objectives, indicators and associated reference points for the maintenance of biodiversity, productivity and water quality within ecosystems of concern. The framework also proposed a means for operationalising the precautionary approach to ecosystem-based management, and noted the importance of defining ecosystem management areas. While examples of the indicators and reference points were presented, it was intended that these would be site and industry specific.

At the request of the NPC, a WGEO was struck by DFO's Oceans and Science sectors to further the operationalisation of the ecosystem – based management framework. At its initial meeting, the WGEO recommended that a workshop be held to define the ecosystem features to be conserved, and the indicator framework to be used. It was agreed that two workshops planned for fiscal year 2000 – 2001, and funded by research monies (DFO Strategic Science Funds and ESSRF), would be combined to achieve the goals of the WGEO.

General Objective of the Workshop

The overall objective of the workshop is to identify ecosystem-level objectives, with associated indicators and reference points, which could be used in setting up and implementing management plans for ocean activities and ultimately integrated management plans for ocean areas.

Workshop Tasks

The framework presented to the NPC proposed that human activities should be managed so as to maintain within acceptable bounds:

1. The diversity of ecosystem types
2. Species diversity
3. Genetic variability within species

4. Productivity of directly-impacted species
5. Productivity of ecologically-dependent species
6. Ecosystem structure and function
7. Water quality (this was added subsequent to the NPC discussion, with a view to ensuring completeness of the suite of objectives)

The following tasks will be pursued at the workshop:

Task 1: Review NPC ecosystem – level objectives for completeness and develop descriptors for each.

Task 2: Review case studies on the use of ecosystem-based approaches, and evaluate their use of indicators and the degree to which they meet ecosystem – level objectives

While the objectives have so far been determined to be appropriate, descriptors for each objective are required in order to clarify what they encompass. This will be facilitated by considering indicators and reference points associated with each objective. As well, it is necessary to confirm that this is a comprehensive suite of objectives.

Task 3: Review assessment approaches (e.g. IBI, Ecological Integrity, TLA and others) that consider the status of indicators pertinent to each ecosystem objective. This would include the strengths and weaknesses of these approaches, weighting issues, correlation problems, use of traditional ecological knowledge, and impacts of decision-making (including decision rules)

To facilitate ecosystem-based management, a common approach to the consideration of sets of indicators, in relation to reference points, would be useful. Various approaches to categorizing and describing indicators are available (the IBI approach used in habitat-related issues and the TLA used in fisheries situations are two examples). It would be useful to examine the various approaches, their strengths and weaknesses, and other issues.

Task 4: Define research and management directions for the future

Research needs associated with objectives and indicators for ecosystem-based management will need to be identified.

Task 5: Foster common understanding at a national level of objectives for ecosystem-based management

This will be the first opportunity that DFO will have had to discuss nationally, at the bench scientist level, specific issues and concepts of ecosystem-based management, in this case objectives and indicators. The workshop will further the communication and development of a common vocabulary and terminology.

APPENDIX 3. AGENDA

TUESDAY 27 FEBRUARY 2001

AM	Welcome & Summary of Agenda / G. Jamieson & R. O'Boyle Objectives for Ecosystem-based Management / H. Powles & C. Mageau Goals of the Workshop / R. O'Boyle & G. Jamieson Current Thinking on Ecosystem-based Management / T. Smith Objectives, Indicators and Reference Points Related to Marine Environmental Quality (MEQ) / H. Vandermeulen & D. Cobb Objectives, Indicators and Reference Points related to Ecosystem Diversity / E. Kenchington Freshwater Ecosystem Productivity: Experiences form the ELA / J. Shearer Objectives, Indicators and Reference Points for Ecosystem Productivity / J. Rice Biological Indicators of Water Quality / S. Samis
PM	Manager's Perspective Plenary Breakout Groups Summary of Breakout Discussions

WEDNESDAY 28 FEBRUARY 2001

AM	Presentations on International Case Studies: Ecosystem Considerations in Fisheries Management: Linking Ecosystem Management Goals with Ecosystem Research / P. Livingston Objectives and Indicators for Ecosystem-based Management: The Antarctic Experience / A. J. Constable Ecosystem Considerations in the Management of Fisheries from the Patagonian Shelf Large Marine Ecosystem / L. Orensanz
	Presentations on Canadian Case Studies: Incorporating Ecosystem Objectives Within Community Based Fisheries Management (The Arctic Experience) / M. Papst & D. Cobb Development of Ecosystem-based Management Objectives and Indicators for the Central Coast, British Columbia / I. Perry & C. Levings Ecosystem Management in the Great Lakes: Thirty years of adaptive learning / K. Minns
PM	Ecosystem Objectives and Indicators in the ESSIM Context / J. Arbour Monitoring Pelagic Ecosystems in the Northwest Atlantic / J. Anderson Approach for Selecting Objectives and Indicators of Ecosystem Health in Marine Coastal Communities (The Laurentian Experience) / J. Munro Manager's Perspective Plenary

THURSDAY 1 MARCH 2001

AM	An Overview of Assessment Frameworks / B. Smiley Regional Ecosystem-level Monitoring and the Index of Biological Integrity (IBI) Concept Applied to the Southern Gulf of Saint Lawrence / G. Klassen & S. Courtenay The Traffic Light Approach / P. Fanning & R. Mohn Large Scale Questions, Small Scale Solutions: Juvenile Atlantic Cod in Coastal Habitats / R. Gregory and D. Schneider Manager's Perspective Plenary
PM	Plenary Breakout Groups Summary of Breakout Discussions

FRIDAY 2 MARCH 2001

AM	Plenary Breakout Groups
PM	Plenary Manager's Wrap-up Adjournment

APPENDIX 4. SUMMARY OF THE PRESENTATIONS AND DISCUSSIONS

DAY 1: OBJECTIVES, INDICATORS, AND REFERENCE POINTS RELATED TO ECOSYSTEM-BASED MANAGEMENT (EBM)

Objectives for Ecosystem-Based Management (Howard Powles and Camille Mageau)
Rapporteur: Kristen Jordan

Presentation Highlights

- After a short introduction by the workshop co-chairs, Glen Jamieson and Bob O'Boyle, a presentation was made by the co-chairs of the National Working Group on Ecosystem Objectives (WGEO), Howard Powles and Camille Mageau, which gave the broader context of the workshop.
- It was first noted that whereas the *Fisheries Act* was population focused, the 1997 *Oceans Act* and Convention on Biological Diversity were ecosystem and species focused respectively. The latter two provide a solid statutory context for ecosystem – based management.
- The operational context involves the two integrated management planning initiatives within DFO – Ecosystem-based Management (EBM) for fisheries and Integrated Oceans Management for the ocean.
- It is evident that a move towards EBM will not only involve the traditional fisheries stakeholders but also a diverse group of stakeholders involved in ocean industries.
- Given the diversity of human activities and stakeholders implicated by EBM, it is imperative that a common set of overarching, clearly understood, ecosystem-level objectives be defined. With this in mind, in the summer of 2000, DFO's National Policy Committee (NPC) adopted a framework for setting ecosystem objectives for integrated fisheries and oceans management.
- The framework proposed that human activities should be managed so as to maintain within acceptable bounds:
    1. The diversity of ecosystem types
    2. Species diversity
    3. Genetic variability within species
    4. Productivity of directly-impacted species
    5. Productivity of ecologically-dependent species
    6. Ecosystem structure and function
    7. Water quality (this was added subsequent to the Policy Committee discussion, with a view to ensuring completeness of the suite of objectives)
- At the request of the NPC, the WGEO was struck by DFO's Oceans and Science sectors to further the operationalisation of the ecosystem – based management framework. At its initial meeting, the WGEO recommended that the current workshop be held to define the ecosystem features to be conserved, and the indicator framework to be used.
- It was particularly important for this workshop to further refine and describe the objectives, whether they be qualitative or quantitative, the indicators associated with these objectives and, if possible, identify important critical limits or reference points.

Discussion:

- There was little discussion on the presentation.

Goals of the Workshop (Bob O'Boyle and Glen Jamieson)
Rapporteur: Kristen Jordan

Presentation Highlights:

- After briefly reiterating some of the workshop's context mentioned by the previous speaker, the objective of the workshop was stated:
  - To identify ecosystem-level objectives, with associated characteristics, illustrative indicators and reference points, which could be used in setting up and implementing management plans for ocean activities and ultimately integrated management plans for ocean areas.
- The focus of the workshop was to be the operationalisation of EBM.
- The five tasks as stated in the workshop Terms of Reference were presented.

1. to review the ecosystem-level objectives provided by the Policy Committee. Are they complete and do they cover our need? Also, for each objective, descriptors are needed to ensure that we have a common understanding of what they mean. The issue of completeness raised the important issue of whether or not ecosystem-level objectives should include socio-economic and institutional considerations. It was pointed out that under the 1999 Food and Agriculture Organization (FAO) guidelines, the dimensions of sustainable development involve the ecosystem, society, economics and institutions. Similar comments have been made by others. The intent of this workshop is to focus on the ecosystem dimension but to allow participants to investigate the other dimensions as the opportunity arises.
2. to review case studies, nationally and internationally, on the use of ecosystem-based objectives, and evaluate their use of indicators and the degree to which the objectives are met. This review may provide guidance on the use of objectives and critical biological properties associated with these.
3. to review assessment approaches that consider the status of indicators pertinent to each ecosystem objective, including their strengths and weaknesses, weighting issues, correlation problems, use of traditional ecological knowledge, and their potential use in decision-making. Contrary to conventional stock assessment, which typically considers two or three indicators, ecosystem assessment could conceivably consider numerous, seemingly disparate, indicators. There have been a number of recent contributions on methods to summarize multi-indicator information (e.g. multi-criteria analysis, multi-dimensional scaling, RAPFISH, etc). We might learn from these. Overall, it was felt important and instructive to consider how best to develop suites of indicators that could be used in monitoring progress against attainment of stated objectives.
4. to define research and management directions for the future and to foster a common understanding at a national level of the objectives for ecosystem-based management, implying the development of a common vocabulary and terminology. The latter is not a trivial task. In the ecological literature, there is a bewildering array of terminology in use, which tends to confound communication. Some commonly agreed to definitions were presented. Hopefully, the workshop can add to the list.

- The workshop agenda was then reviewed, pointing out that on the first day, the objectives and indicators will be discussed in general terms. The second day will be devoted to the case studies. The third day will be devoted to assessment frameworks and the last day to wrap-up discussion. Each day, there will be breakout groups to consider specific questions and issues followed by plenary discussion. However, the agenda would be changed and adapted as required during the workshop.
- The main products of the workshop will be a Proceedings in the Canadian Stock Assessment Secretariat (CSAS), which will document the discussion of the workshop and form the basis of the workshop steering committee's submission to the WGEO. In addition, dependent upon the interests of the presenters, there will be a peer-reviewed volume of the presented papers in a scientific journal.
- After introducing the workshop facilitators, the presentation concluded by stating that we wish to develop a common understanding on objectives and indicators for all participants - scientists, managers and policy makers. It is a workshop in which one should contribute rather than listen. And it is the first step in a process, where we want to see the big picture and leave the specifics to later.

Discussion:

- There was little discussion on the presentation.

Current Thinking on Ecosystem-based Management (Tony Smith)
Rapporteur: Ian Perry

Abstract:

There are currently a large number of initiatives, global, regional, national and local, that are seeking to implement ecosystem-based management. This presentation discusses a few of these, but the overall assessment of the situation is that policy is well out ahead of the practical tools for implementation, including the scientific tools. This arises in part because marine ecosystems are complex, hard to study, and generally poorly understood.

Nevertheless, progress is possible, provided a pragmatic approach is taken. I argue that the focus of this meeting, on development of operational objectives linked to indicators and reference points, represents such a practical way forward, provided the overall process remains adaptive (learn as we go). Progress will require that ecologists (in particular) go out of their way to engage with managers and other stakeholders (industry, conservation groups, community groups, etc) to provide timely and helpful advice, based on current state of knowledge. Development of adaptive management systems that link monitoring and analysis with revisions to management plans and strategies provides the best practical way forward to implementation of ecosystem-based management. As a side benefit, there are likely to be substantial opportunities for scientific learning along the way, particularly from (large-scale) spatial comparisons of ecosystem response.

Some current initiatives are discussed briefly, including development of oceans policies in Canada and Australia, development of "sectoral" approaches (fisheries ecosystem management and integrated coastal management), and "science-based" initiatives [Large Marine Ecosystems (LMEs) and ECOSIM]. A few initiatives in Australia are briefly described. These include

development of ecosystem-based regional marine planning on the North West Shelf, a variety of certification schemes for sustainable fishing (including regulatory, voluntary, and industry-driven), and a study to identify robust indicators for the ecological impacts of fishing.

The talk concludes with some gratuitous advice to marine ecologists about engaging in ecosystem-based management.

Presentation Highlights:

- The key points for this presentation are that policy development is ahead of science, and there is broad community, policy, and legislative support to the extent that global, regional, national, local initiatives are now underway. However, these initiatives generally lack tools for the required tasks.
- There has been lots of thinking and debate, but little practical experience as yet.
- Implementation of an ecosystem-based approach needs partnerships, i.e. among other disciplines, such as social, economic, and the policy community. This will require the development of pragmatic and adaptable approaches.
- Common themes for ecosystem-based management are: sustainability, health, integrity, structure and function, ecosystem services, and that the approach must be holistic, i.e. that it include social, economic, environmental, and ecological aspects.
- In Australia, an Oceans Policy has been in place since 1998. Implementation of this policy will result in the development of regional marine plans, the first of which is underway in the Southeast. The spatial units for the regional plans are based on a bio-regionalisation approach to define appropriate regions and scales. This bio-regionalisation approach is built on physical and biological criteria, not political boundaries, although it is difficult to include large-scale interannual variability. "Strategic fishery assessments" are also being developed that focus on impacts of fishing on species, habitats, and food webs. the ecological indicators being used in these strategic assessments will be tested for robustness using simulation methods.
- Theoretical ecology can provide a number of lessons for development of ecosystem-based management approaches. These include practical experience, ecosystem modeling, the design of monitoring programs, and insights into choice of indicators.
- It must also be remembered that indicators are usually proxies for underlying quantities of actual interest and direct management relevance.
- There is lots of interest, debate, and discussion regarding Ecosystem-based Management, but so far no one is doing it yet comprehensively. Therefore, get on with it, and be adaptive.

Discussion:

- Elaboration on the meaning of robust indicators was requested. The particular project referred to will review indicators of the impacts of fishing, e.g. by-catch, habitats, food webs, etc. It will look at what has been used and what looks promising. In its second phase, it will test various indicators for robustness by simulation modeling. The idea here is to make sure that the indicators being used are actually measuring what we think they are measuring.
- It was commented that in this workshop, we are driven by biological aspects, but many places elsewhere are looking at including social and economic indicators, e.g. Gross Domestic Product. These seem like enormous indicators. It was replied that to make progress

on ecological indicators, we need to consider and to use other indicators at this level, e.g. economic indicators that relate to fishing. This is being done in Australia with regard to reporting on fisheries "ecologically sustainable development".

- How is Australia dividing up the coast in the bio-regionalisation project – by biological or political boundaries? Australia has attempted to use physical and biological criteria, not political boundaries. These criteria are used as a basis for planning, but there can be problems in taking account of environmental variability. i.e. they tend to produce fixed or static boundaries.
- Our workshop is timely and pertinent to the global discussion of these topics.

Presentations on Objectives, Indicators and Reference Points

Objectives, Indicators and Reference Points Related to Marine Environmental Quality (Herb Vandermeulen and Don Cobb)

Rapporteur: Simon Courtenay

Abstract:

The concept of Marine Environmental Quality (MEQ) and associated objectives, guidelines and criteria is presented in the *Oceans Act* as a tool for implementing Integrated Management Plans and associated plans for Marine Protected Areas. A "Glossary of ecological terms used in the *Oceans Act* and its implementation programs" is useful in providing a context for MEQ program activity. MEQ is an overall expression of the structure and function of the marine ecosystem.

MEQ objectives development encompasses the establishment of ecosystem objectives, following a framework from the Working Group on Ecosystem Objectives. Objectives lead to the development of scientifically defensible indicators and monitoring programs (including performance measurement), with associated reference points.

Most early federal activity on MEQ was lead by Environment Canada (DOE) with a pollution focus. During the 1990s DOE and DFO worked together to develop a broader view of MEQ, one that focuses on ecosystem structure and function.

Aspects of ecosystem structure and function can be a basis for establishing a common roster of ecosystem objectives. By considering aspects of ecosystem structure and function, intuitive groupings of ecosystem objectives fall out: I. Physical; II. Chemical; III. Biological; IV. Human. Examples are provided of the types of phrases that could be incorporated into an ecosystem objective under each of the above categories (and how they could link to subsequent indicator development). An ecosystem objective from Lake Ontario is used for illustrative purposes.

Presentation Highlights:

- MEQ is a consolidated concept (not just about pollution!), encompassing structure and function.
- A glossary of terms in the *Oceans Act* has been useful in providing a context for MEQ program activity (definitions vary in the literature, making it difficult to agree on concepts).

- MEQ aims to tie objectives to ecosystem management plans that have been collaboratively developed.
- MEQ categories are as follows: physical (habitat), chemical, biological and human.

Discussion:

- One challenge is tying MEQ to monitoring programs. Often MEQ is not tied to management's work. Certain indicators have been developed for each MEQ category, but not all are being implemented.
- There have been advances in this field on the East Coast, based on looking at the structure and function of ecosystems (at lower levels of the food web). Protocols have been established for a zonal program encompassing three regions, and an operational structure is in place to collect, assess and report on data (with physical, chemical and biological dimensions). Other examples of applying MEQ exist in Europe.
- Some indicators will generate meaningful reference points with sound scientific understandings. Indicators can give structural and functional information about systems that aren't well understood, so it's still important to collect the data.
- Ecosystem objectives often conflict – maximising some may jeopardise others. The aim should be to optimise all within this multiple objective context.

Objectives, Indicators and Reference Points Related to Ecosystem Diversity

(Ellen Kenchington)

Rapporteur: Don Cobb

Abstract:

Over 170 countries have signed the legally binding agreement referred to as the Convention on Biological Diversity (CBD). The responses from governments to this agreement are now familiar concepts to those engaged in resource conservation activities. These include integrated coastal management, the establishment of marine protected areas (MPAs) for conservation and sustainable use, and identifying priority components of biodiversity and monitoring their status and threats. In order to implement the latter, an operational framework must be established with objectives, indicators and reference points that accurately reflect ecosystem properties. This framework is required in order to satisfy the needs to monitor and assess. Clearly, other approaches may proceed in the absence of such a framework and indeed the MPA concept, or preservation of a "slice of life", may be implemented for purely aesthetic reasons by conserving flora and fauna in the narrowest sense (i.e., local patches). The concept of biodiversity is complex and has often been used ambiguously in fisheries science to refer to species composition. However, while the main features of diversity include species diversity, other important elements are genetic diversity, functional diversity and landscape and temporal diversity. For each of these categories an objective is proposed (e.g., maintaining species diversity). This is related to a concept within the objective, e.g., species richness, which in turn can be measured using a suite of indicators, e.g., species number and/or taxonomic diversity. This achieves the monitoring function. Reference points for each indicator must then be established through empirical studies to reflect threats to the system in order that remedial actions can be implemented. Some examples of this approach are given below.

Element	Objective	Concept	Performance Indicator	Reference Point
Species Diversity	Maintaining Species Diversity	Species Richness	Species Number Taxonomic Diversity	
		Species Heterogeneity	Simpson's Index	
			Pielou's Evenness	
Ecosystem Diversity	Maintaining Functional Diversity	Functional Guilds	Number and Relative Proportion	
		Trophic Levels	Number and Relative Biomass/Production	
		Stability	Persistence Over Time	
		Resiliency	Recovery after Disturbance	
		Habitat Complexity	Indicator Species and Aerial Scale	
		Critical Habitat	Size and Spatial Complexity	
		Keystone Species	Abundance, Biomass, Population fluctuation	
Landscape Diversity	Maintaining Landscape Diversity	Water Mass Integrity	Water mass characteristics	
		Benthic Fragmentation	Relative proportion of habitat and Nearest Neighbour Distances	
			Habitat Size	
		Critical Habitat	Size and Spatial Complexity	
Genetic Diversity	Maintaining Genetic Diversity	Effective Population Size	Ne (Effective Population Size)	
		Proxy for Ne	Nc (Census Population Size)	
		Constraints on Nc	Sex Ratio	1:1
			Population Fluctuation	
		Genetic Diversity	Inbreeding	
			Number and Size of Spawning Populations	
			Population Fragmentation and Range Contraction	
		Selection	Selection Differentials	
Within Species Diversity	Preserve Population Structure	Population Size	Nc	
		Population Structure	Number of Spawning Components	
			Age Structure	
		Metapopulation	Incidence Function	
		Reproductive Capacity	Spawning Stock Biomass	
			Nutritional Status	
			Fecundity	

Where do we start? Species are the most practical and widely applicable measure of biodiversity. They are the common currency for research and management, and have a well established standardized code of nomenclature. There are a wide variety of measures available that can capture information on species diversity. Many of these have been used extensively in the literature and their performance has been well calibrated and their strengths and weaknesses documented. As a group, they are more amenable to monitoring approaches or for use in experimental situations where relative changes can be described. Species lists may be the most cost effective of these measures as they contain secondary information on functional groups and taxonomic diversity.

Presentation Highlights:

- The speaker reminded the participants of The Legal Framework: i.e., 1992 Earth Summit (Rio), the Convention on Biological Diversity, the 1995 Conference of Parties (Jakarta) to implement the CBD with respect to marine and coastal biodiversity; and the Canadian Biodiversity Strategy (Strategic Direction 1.59).
- Several different types/levels of diversity were presented: biodiversity, ecosystem (including functional diversity), landscape (spatial diversity), genetic, population.
- It was pointed out that the objectives used to evaluate the performance measures will not apply equally well to all species. The framework must respect the biological properties of a diverse array of organisms.

Discussion:

- The challenge for DFO is to work closely with other stakeholders to implement EBM. What processes are in place that will allow this?

Freshwater Ecosystem Productivity: Experiences from the Experimental Lakes Area
(John Shearer)
Rapporteur: Herb Vandermeulen

Abstract:

The Experimental Lakes Area (ELA) is a DFO facility specifically established to conduct ecosystem-scale experimental manipulations and long-term monitoring in small lakes and their watersheds. ELA researchers have conducted more than 40 ecosystem-scale experiments, and have investigated the effects of various stressors on the structure and function of lake ecosystems. In addition, ELA researchers maintain a long-term monitoring program wherein natural lakes are sampled for a variety of variables, as a means of assessing natural variability in these systems. The results from these studies also provide a baseline or reference against which the experimental systems may be compared. Not only are the lakes themselves sampled, but also the precipitation, the inflow and outflow of streams, and where appropriate, some aspects of the terrestrial catchments.

One key to the success of the ELA program has been the maintenance of an integrated, multi-disciplinary team of researchers, based at the Freshwater Institute. This team includes expertise in the physical, chemical and biological sciences, and in integration of these fields. The team members are primarily interested in field research, and spend significant periods of time each year doing field studies at the ELA. Where appropriate to fill gaps in expertise, ELA researchers collaborate closely with other scientists from universities and other agencies.

The most basic master variable in the ELA lake ecosystems is water movement, be it inflows, outflows, precipitation, or internal circulation. Water movement is essential for nutrient inputs and cycling, for bringing in dissolved organic carbon, which reduces primary productivity, and

for all aspects of chemical cycling, including movement of toxic substances. A second important variable is solar radiation, including photosynthetically available radiation (PAR) and UV-B. PAR is essential for photosynthesis, while UB-V is harmful to organisms living in streams or shallow lake water. PAR flux is also highly correlated with heat input to the lake, particularly to the water below the mixed layer.

Dissolved organic carbon (DOC) is a key chemical variable in ELA lakes, particularly because of its effects on primary productivity. Phosphorus, as the usual limiting nutrient for phytoplankton productivity, is also a key variable. pH is important because it can affect a variety of in-lake chemical and physical processes.

Key biological indicators vary according to the stressor and the particular ecosystem under stress. This means that, if possible, we need to monitor all known levels of the food web. Organisms lower on the food chain (e.g. algae) may respond rapidly to stress and undergo dramatic species shifts, but community productivity may not change significantly. Higher organisms, such as predatory fish, are longer lived and their population responses may not be obvious until after the food web has been severely damaged.

The ratio of respiration to production (R:P) is a key biological or physiological indicator that can be useful for detecting ecosystem health. However, it is often difficult to measure in real ecosystems.

Several general lessons learned from the ELA research include:

- Continuous, long-term, broadly-based monitoring records are critical for detecting ecosystem change.
- The interfaces within or between ecosystems, and the interactions across these boundaries, are important to understanding ecosystem function.
- Different regions within ecosystems (e.g. pelagic and littoral) may respond differently to a stressor.
- Biodiversity is an important determinant of an ecosystem's functional resistance to stress. Stress reduces biodiversity.
- We need to understand ecosystem processes or functions, as well as ecosystem structure.
- Interdisciplinary collaboration and integration is essential to the understanding of ecosystems.

Ocean systems are larger and more open than small lakes. They will be more difficult to understand.

Presentation Highlights and Discussion:

- The ELA is a DFO facility in northwestern Ontario established to conduct ecosystem experiments and long-term monitoring in small lakes and their watersheds. The ELA facility includes 58 small lakes and their watersheds. Some have been studied for over 30 years. Early work centered on eutrophication issues. Later, acidification studies were a major focus. Currently, mercury and climate change (greenhouse gases) studies are the primary research topics.

- ELA also has a long-term ecosystem monitoring program which has helped to describe natural variability and climate change. Schindler has developed a model of acid rain, global warming and ozone depletion affecting lake ecosystems in the Boreal Shield. Long-term data (e.g. from Lake 239) include productivity of phytoplankton and periphyton and some information on zooplankton and small fish - relatively good information exists on some of the larger fish species.
- Key variables tracked during long-term ecosystem monitoring include:
  - physical - water movements (hydrography, mixing);
  - chemical - DOC, phosphorus, chemical cycling (nutrients, toxins);
  - biological - must monitor at multiple food webs levels as some levels don't give enough early warning of the problems present (monitoring fish alone is not enough, must examine algae and their population shifts as well); ratio of respiration to production is important;
  - solar radiation - PAR, UV-B; chemical variables (Dissolved Organic Material (DOM)/ DOC, phosphorus, pH) tend to control solar input into lakes
- ELA was first established to solve a "big lake" problem (eutrophication). ELA researchers have examined the issue of scaling from small lakes up to the large (Lake Superior) level. Some ecosystem aspects scaled well, others didn't (e.g. mixing). The ELA experience with scaling may be useful in an ocean context.
- It is important to understand ecosystem processes/functions, as well as structures. Biodiversity is key to an ecosystem's functional resistance to stress. Ecosystem interfaces are also important (sediment / water column; water / land; water surface / atmosphere). There are littoral versus pelagic differences in responses to stress.
- Continuous long-term monitoring (decades) is critical to answer the main questions confronting ecosystem science (Likens' recent paper). Long-term monitoring records will help to estimate the range of natural variability, and to detect significant trends or changes. Effective ecosystem research requires interdisciplinary teams; collaboration / communication; long term funding; and dealing with larger spatial scales and more open systems.

Objectives, Indicators and Reference Points for Ecosystem Productivity (Jake Rice)
Rapporteur: Colin Levings

Abstract:

The talk reviews first how objectives and indicators are chosen for simpler single species cases. It then proceeds to consider how to expand that knowledge and experience to the broader – and harder – ecosystem context. Setting objective moves from the conceptual to operational, as well as from objectives to indicators to reference values. Signal detection theory is a useful approach for evaluating potential operational objectives, by focusing on hit rates, miss rates, and false alarms.

Even in the single-species case, "productivity" can be made very complex. However at this scale it is the net result of increasing the size of a stock by recruitment, and somatic growth, and decreasing it through mortality, both natural and harvesting. The ecosystem parallels may be

captured by biomass increases due to primary production and subsequent energy transfer, diminished by respiration costs and total mortality.

At the conceptual level, there are very few core single species objectives. One is keeping recruitment as high as possible, given a variable and uncertain environment. Another is keeping total mortality sustainable, and well below the maximum sustainable when the population is low. Where somatic growth is considered, it is usually with regard to density dependent factors where the concern is that the population does not grow too large. The corresponding ecosystem conceptual objectives are keeping primary production, predation linkages, and non-predation mortality within historic variation.

In the single species case, the operational recruitment objective is not numbers of recruits, but spawning stock biomass (SSB). The operational objectives for total mortality also usually are achieved through the surrogate of keeping fishing mortality sufficiently low. The talk reviews the reasons why these surrogates are essential, and why similar reasoning applies to ecosystems.

Ecosystem experience with primary production has been largely with coastal eutrophication, where the operational objectives are again nutrient and oxygen levels, not production itself. Production at higher trophic levels has been approached with P/B ratios, usually for only a few species, and usually without specified reference points, because there is so much uncertainty in both the numerator and denominator of estimates. Trophic transfers have been approached through trophodynamic modeling. However, the only analytical and operational successes have been when a small number of linkages have been used in a structured and focused way. Examples from CCAMLR and the European Union are presented. For ecosystem mortality rates, predation is the only term in the natural mortality portion of Z for which there have been attempted to qualify its effect separately, for example with Multi-species Virtual Population Analysis (MSVPA). Examples form the North and Baltic Seas are given. Only for catastrophic events like Exxon Valdez are larger scale mortality rates estimable.

The many dangers of relying on ecosystem models for choosing and monitoring ecosystem objectives are reviewed. Several classes of ecosystem models should be avoided in setting operational objectives and monitoring performance, because of either high miss rates or high rates of false alarms. Models that contain many inputs that cannot be updated regularly have high inertia (many misses) and may be hypersensitive to those terms that are updated (false alarms). Models that contain functional forms selected for tractability or convenience, but poorly justified on empirical grounds, may be misleading, especially if the functional forms are non-linear. The non-linearities make parameters very difficult to estimate robustly, and model performance prone to false alarms, and terms in the equations evolve a reality that they do not actually have. Models which leave out key processes are also present dangers if the process actually would affect model dynamics strongly were they present. Size or life-history structured omnivory are particularly important in this context. Finally, models borrowing structure largely from terrestrial ecological theory should not be used, because key processes like habitat structure, environmental forcing, and metapoesis are very different between terrestrial and marine ecosystems.

Strongly data-driven models do have promise as sources of operational objectives. The slope and intercept of size spectra and P/B ratios for some classes of organisms show substantial promise, as does selecting and managing on the basis of most-sensitive species. Suggestions are also offered for how to eventually make ecosystem models more useful in seeing operational ecosystem objective.

Presentation Highlights:

- Dr. Rice contrasted the task of setting objectives for single species management with that of ecosystem management
- Both single species management and ecosystem management use surrogates of productivity, energy flow and trophic transfer.
- In spite of the long history and experience with single species management, it has been difficult to set operational objectives and to get compliance where they have been set. It will even be harder for ecosystem management.
- A key point is that conceptual objectives must be agreed upon before operational objectives.
- Four types of dangerous models were described for those contemplating the use of models in ecosystem management and he warned they frequently generate misses and false alarms.
- Dr. Rice held out some hope for models with a sound theoretical basis such as size spectra. Monitoring of selected species known to be key trophic links (e.g. sand eels, capelin) was also supported.
- In general there is a need for much more empirical work to test existing and proposed models.

Discussion:

- A participant noted that work at the ELA offered useful options for experimental manipulations, procedures not available to people working in the ocean. Coupled biophysical models such as those in Global Oceans Ecosystems Dynamics (GLOBEC) may be alternative. Dr. Rice pointed that data on ocean circulation are key to such models.
- A participant commented that primary production (e.g. chlorophyll a) is an important tool for monitoring ecosystem performance.
- A participant commented that percentage removal of a particular trophic level ("fishing down the food web") was another possible model. Dr. Rice observed that production is always a good index but can be hard to measure. Even production:biomass ratios can be a problem because of the variation in biomass observed in ocean biota.

Biological Indicators of Water Quality (Steve Samis)

Rapporteur: Bob O'Boyle

Abstract:

Water quality is described conventionally in chemical or physical terms. However, during the last twenty years or so many sub-lethal bioassays have been proposed or developed for use in aquatic environments, and several of these have been evaluated during collaborative exercises by various intergovernmental agencies; a handful of those have emerged as being consistently successful and are now used routinely to complement conventional chemical analyses of water quality. Measurements at four levels of biological complexity are discussed here: biochemical

measurements (such has hepatic mono-oxygenase induction or acetylcholinesterase inhibition), histopathological indices (e.g., lysosomal stability), whole organism changes (e.g., oyster embryo bioassays, measurements of "scope for growth") and measurements of (usually benthic) community structure. At one end of this scale, biochemical measurements tend to be rapid, specific to a particular cause but have low ecological relevance; at the other end of the scale, community structure measurements are obviously relevant ecologically, but respond to non-specific causes and tend to be retrospective as opposed to anticipatory. These measurements therefore provide potential tools to answer questions about biological effects of water quality; as in any scientific study, the trick is to identify the appropriate question(s).

Presentation Highlights:

- Water quality can have impacts at various levels of the ecosystem and thus it is important to measure these impacts at these various levels.
- Four levels were considered - biochemical, cellular, whole organism and community.
- Measurement at each level cannot provide an overall index of water quality and must be considered in the appropriate context. For instance, biochemical measures tend to be specific but can provide an early warning of impacts. Measurement at this level however can have low ecological relevance.
- Water quality changes at the community level, on the other hand, can have high ecological relevance although the specificity and timeliness is low.
- Overall, it is important to have indicators of water quality at the four levels of the ecosystem.

Discussion:
There was limited discussion following the presentation.

Managers' Perspectives on Objectives, Indicators and Reference Points

Rapporteur: Ian Perry

A Habitat Manager's Perspective (Bruce Reid)

Presentation Highlights:

- The key role of a Habitat Manager (in the Pacific) is to protect and conserve fish habitat. The general roles are 1) to integrate resource planning; provide project reviews, 2) to conduct compliance monitoring; to provide enforcement, and 3) to provide education.
- Decisions are made using the best available science, local knowledge, experience, policy, instinct, and ecological considerations.
- An ecosystem approach has been used for years, e.g. taking a whole watershed view and including broad ecological considerations. The objectives and indicators that are followed are those that are practical and pragmatic, repeatable, cost effective and helpful for operational staff for planning and project review.
- There is a need to clearly state ecosystem objectives and indicators at planning.
- Indicators must not be used as excuses for avoiding habitat impacts; for avoiding corrective actions; or a reason to use dangerous models.
- Habitat managers need Science help in setting priorities for watershed planning; foreshore development; urban development; forestry; and agriculture.

A Fisheries Manager's Perspective (Greg Peacock)

Abstract:

External clients in most East Coast situations are commercial fishers although almost all of the comments could also and equally apply to recreational fishers. As such fishers operate in an environment of revenue generation. Therefore asking fishers to do something is always weighed against the positive or more likely negative impact from a revenue generation perspective.

In order to focus on the primary objective of revenue generation (other factors such as community support, quality of life, etc. coming in varying degrees of less importance) fishers operate almost totally in the venue of single species management. It is the exception to see multiple licenses held by a fisher be considered as a block for management or revenue generation purpose. The efforts on the East Coast to move towards the "core" classification to try and move fisher consideration in the multiple species concept has largely failed.

Within the current fisheries management regime, there are both primary and secondary layering of controls, requirements or demands which create significant levels of stress within fishing groups and quite often lead to open opposition to initiatives being contemplated:

- Conservation related-Total Allowable Catch (TAC) or other biological limitation designed to conserve resources within the caveat of normal fluctuation. In extreme situations this can include managing major growth and decline.
- Governance-Conservation Harvest Plans (industry), in-season management applications (industry), industry management boards, Joint Project Agreements, accountabilities and allocative/biological penalty processes. We give to industry management responsibility(that which DFO often did poorly), management accountability and we say to industry "to get this please pay up"
- Industry implemented conservation applications such as closures, by-catch limits, limits on size and sex, license fees, etc.
- Allocation/Access-commercial vs. recreational vs. aboriginal; fg vs. fg vs. mg; small boat fleets vs. big; quasi property rights vs. competitive fisheries; concentration of ownership vs. owner/operator.
- Social/Economic-coastal community support; common property vs. quasi property rights; concentration of ownership

Now if you add to this the secondary layering of: Species At Risk Act (turtles, whales, porpoises); Oceans (MPA, ESSIM, oil & gas, cables, bottom impacts); Forage species; Emerging species and the displacement effect; Aquaculture and the replacement of traditional fishing sites; Coast Guard demands of Canadian Steamship Inspection (CSI), safety, ocean dumping etc.; Fisherman Professionalization and Code of Conduct; Ecosystem Management.

All of this represents constant and unequal change and if we are to be successful it will be because we can successfully manage change.

So how should we proceed if one were looking at this from the external client perspective?

- Objectives need to be justified as to why they are important. The buy in is essential otherwise the exercise will fail.
- Well-defined ecosystems are required. The bioregionalization concept seems appropriate because there is the need to treat perceived like ecosystem components the same. This is the "east side/west side mentality in fishing ports"
- Well-accepted indicators that address critical issues within the ecosystem model are essential. The industry operates on a critical point assessment, Hazard Analysis Critical Control Point (HACCP), on a daily basis and they want and need this to respond in a similar fashion.
- What will be the quantified impact on the ecosystem and the human user?

So what do we need? Objectives that are clear and real, relatively simple objective definitions that are acceptable to external clients and are measurable with well defined resultant actions. Very much like the dialogue in several Precautionary Approach (PA) documents.

Finally there is a great deal of uneasiness over the newfound role for ecological based (non-consumptive user) groups. Industry sees ecosystem approaches as a tool for attacking commercial fishers in a manner previously not provided. Therefore a cautionary note is presented which will need to be addressed in the buy-in.

Remember "It all comes out of the cod-end". Commercial fisheries are important and their opinions count. If this is to succeed it needs fisher buy-in. This can and will occur, most probably in areas less favorable to quasi-property rights first but it will come IF we don't ignore the realities of the fishery.

Presentation Highlights:

- The clients (fishing industry) for DFO Fisheries Managers deal with single species perspectives. Fisheries Managers need to be able to tell clients that ecosystem management "will be good for them"! But it is unclear that ecosystem-based management approaches will accommodate TAC's, changes in governance to clients, allocation and access issues, greater community involvement, Species at Risk and *Oceans Act* issues, and transport and marine safety issues.
- Fisheries Managers are trying to manage change, and to help clients manage change. In particular, there is a need to get buy-in on Ecosystem Objectives from the clients. This would be helped immensely by having well-defined areas – i.e. bio-regionalisation exercises, a few critical indicators for clients to understand, and clear and measurable objectives with well-defined result/action levels.
- "Non-consumptive use" lobby groups strike fear in fishers, and many fishing groups see ecosystem-based management as a door for "green" groups to take over. Therefore, there is a need to de-link "green" issues from ecosystem-based management.

An Oceans Manager's Perspective (Bob Rutherford)

Presentation Highlights and Discussion:

- Oceans Managers face more complex management issues, e.g. seabed uses, hydrocarbon extraction, etc.
- They face a hierarchy of "visions" or issues, from international treaties, to National concerns, to local issues.
- There has been a tendency to let local community interests dominate – the problem, therefore, is how to link these into the larger National and International visions.

Discussion Highlights on Morning Presentations

- It is hard to link ecosystem-based management to practical, mgt level. People talk about need for monitoring programs, but never linked to tangible management work.
- Regarding categories of ecosystem objectives, some indicators will generate meaningful reference points- sound scientific understanding. Other objectives might require monitoring of structure and function of systems that we don't understand yet. Sometimes no scientific consensus yet on the structure and function, but we still should monitor.
- Has there been a leap in the science in the past five years? Lots of theories and indices, but lacking on the ground monitoring. Could go forward with an integrated management plan that forces people to do the monitoring. Lots of upper level strategic frameworks but need to operationalise on the ground.
- Re biodiversity, concentrate on characteristics that are amenable to monitoring
- Re lakes vs. oceans, lakes smaller, relatively more closed, so easier to measure transfers in and out of system (e.g. located at headwaters), pristine systems. Can the results be scaled to oceans? LOLSS study tested the scalability of ELA research to larger lakes (e.g. Superior) – some variables scale well but others didn't.
- Importance of continuous, long term monitoring records (over decades) discussed. Helps to estimate range of natural variability, and to detect significant trends or changes.
- Differing regions of ecosystems respond to external stressors in different ways (e.g. pelagic vs. littoral)
- Biodiversity an important determinant of an ecosystem's functional resistance to stress.
- Need to understand both processes/functions and structures.
- Need for collaboration and integration among specialised experts. Helps to understand physical, chemical and biological interactions.
- Productivity, characteristics, indicators.
    - Start with conceptual, then go operational.
    - Single species conceptual objectives an important starting point. E.g. keep recruitment as high as possible; keep mortality below sustainable level. Ecosystem conceptual objectives: keeping primary productivity, predator-prey linkages, and keeping non-predation mortality low (within normal range of variation)
    - Model possibilities: Data drive models – slope and intercept of size spectrum; possible progress with P/B ratios, but only if B is monitored well. Still need to identify reference points. Also, success with selecting particularly sensitive species (both biological and statistical)

- Ecosystem level targets harder than single species targets
- Re productivity, use surrogates, not productivity itself
- Biochemical measures are specific, provide early warning of effects but are of low ecological relevance. Community changes have high ecological relevance but the specificity and timeliness is low.
- The issue of the soundness of the indicators was raised. Important qualities are sensitivity, timeliness and connectivity between different levels of integration –e.g. water quality: from biochemical, to individual and community level. In addition, 'miss and false alarm' rate or performance is equally important: one can refer to signal examination theory.
- A related issue was raised in that we are primarily interested in the relative performance of indicators and we shouldn't need to have a full understanding of the ecosystem in order to apply them.
- Connectivity to society is important; in this respect money can be a good economic indicator. However DFO mandate includes goals like conservation and no negotiation can be accepted at certain levels. We thus need to set the biological limits.
- The issue of the workshop's scope was raised. Specifically, there were concerns that the workshop was too focused on the biological issues and was ignoring the other socio-economic dimensions. It was replied that we know these exist and are important but that in order to keep the workshop focused, only the ecosystem was being considered. A different set of participants would need to consider the other dimensions, perhaps in a future workshop. The role of technical experts and policy makers was discussed. Overall, it was considered that the technical experts are in the best position to explain the consequences of making various choices, whereas society and policy makers should make the decisions on those choices and the acceptable levels of risk.

Breakout Group Presentations and Plenary Discussion

Instructions to Breakout Groups

The workshop co-chairs first reviewed the framework presented to the National Policy Committee (NPC). One of the goals of this workshop is to identify a broad set of ecosystem level objectives that could be applied to Canadian marine ecosystems. Based on the day's presentations, which provided an overview of some current ideas on ecosystem-based objectives, indicators and reference points, the following were to be undertaken:

- In a bullet-heading format, list the full suite of ecosystem objective categories, which are felt to be suitable for Canada. Build upon the objective categories presented by today's speakers as well as that of the NPC.
- For each objective, provide a description of what is implied. Use sub-headings to enhance this description if necessary.
- Provide examples of indicators and reference points for each objective, based on today's presentations and your own experience. This is simply to enhance the description as this is not an indicator development exercise! That will be a later lower level, more technical process of quantification. So aim high to flesh out characterizations of desirable and relevant ecosystem objectives.

In formulating their answers, the breakout groups were to keep in mind the following:

- Ecosystem objectives are intended to lead to overall measures of Marine Environmental Quality / Ecosystem Integrity / Ecosystem Health (depending upon your terminology or management bias).
- It should be possible for managers (Integrated Management, Fisheries Management, etc.) to use your list of ecosystem objectives to rationalise management plans (indicator development, reference points, targets, monitoring, etc.) which are specific to particular management areas and ecosystems. Note however, that not every ecosystem objective will be appropriate everywhere and will have equal weight in all management plans.
- The case studies and frameworks that will be presented later on in the workshop will provide more ideas for the development of the list of ecosystem objectives. Later break-out groups will allow for additional modification of ideas developed in these groups.

The compositions and discussions of the breakout groups are presented below, along with points raised in the subsequent plenary session, when each group presented its findings.

To provide for diversity of opinion and lots of opportunity for input, five breakout groups were formed. To ensure a cross section of representation on these groups, the participation in each was as follows:

Group 1	Group 2	Group 3	Group 4	Group 5
I. Perry (chair)	**S. Courtenay (chair)**	**H. Vandermeulen (chair)**	**J. Munro (chair)**	**J. Arbour (chair)**
A. Smith	P. Livingston	D. Cobb	J. Karr	C. Levings
J. Rice	D. Radford	A. Constable	L. Orensanz	G. Klassen
J. Anderson	K. Minns	**E. Kenchington (rapporteur)**	P. Fanning	R. Mohn
H. Powles	N. Harrison	J. Shearer	I. Yeon	B. Smiley
S. Campbell	B. Atkinson	M. Papst	T. Anderson	L. Park
M. Chadwick (rapporteur)	C. Savenkoff	M. Sinclair	R. Bradford	B. Chang
W. Franzin	**J. Pringle (rapporteur)**	J. Runge	J. Boulva	J. Gagné
J. King	B. Shaw	T. Perry	A. Sinclair	**K. Hyatt (rapporteur)**
R. Gregory	C. Davies	D. Armstrong	N. Sloan	C. Robinson
C. Millar	L. Burridge	R. Rutherford	C. Mageau	P. Hale
M. Gilbert	M-F. Dalcourt	R. Mylchreest	**P. Boudreau (rapporteur)**	P. Cranford
D. Andrie	R. Huson	M. Clemens	J. Piuze	J. Mathias
D. Boisvert	F. Scattolon	M. Joyce	S. Samis	F. Hietkamp
C. Jones	M. Pakenham		G. Peacock	B. Reid
			B. Steven	

The group chair is indicated in the first row. The Chair was to lead the discussion and ensure that rapporteur's writings and notes were correctly incorporated into the final report. The rapporteur would be responsible for recording the group's discussions. The group could decide which person was to present the results of the discussion to the plenary. G. Jamieson, B. O'Boyle and the workshop facilitator would float among the groups.

Breakout Group 1

Group Findings:

- This group recommended that the seven ecosystem objectives proposed to the NPC could be simplified and divided into three main foci: conservation of species; conservation of habitats; and conservation of the natural size structure of the system. A lower-level priority would be conservation of productivity; it was felt that this objective would be partly covered by the focus on species, size and habitat.
- The group felt that it was important to maintain a diversity of ecosystem types but that this focus was not a practical management objective. There were several reasons for this decision. First, it was felt that too much effort would be spent on defining the zones or types and their important ecological discontinuities. Second, it was felt that the focus should be on how people would be incorporated into the ecosystem unit. Preservation of functional diversity was not felt to be a useful objective because in areas like the prairies this characteristic had not necessarily changed despite large changes in species composition.
- Conservation of species diversity was felt to be an important objective with several caveats. First, species diversity was not considered to be a sensitive indicator of ecosystem change. The emphasis should be on the prevention of loss of rare species. A good indicator might be analysis of k-dominance curves. Other indicators of monitoring species diversity might be achieved by careful monitoring of keystone species. There was some discussion of species introductions but it was recognized that much of Canada was only recently glaciated and therefore unused niches were likely available in the aquatic environment and, as such, new species were not necessarily a bad thing. There was also some discussion of ecosystem resilience as a desirable management objective. In general, it was felt that greater species diversity conferred greater resilience.
- Conservation of habitat was considered another top-level objective. Rare habitats (e.g. sponges and corals) in particular should be monitored because they would be most sensitive to small changes. It was noted that habitat must include water quality and be particularly focussed on the habitat needs at life cycle bottlenecks.
- Conservation of size structure would be a good management objective that would ensure productivity of species and ecosystems. This objective was considered to also meet trophodynamic considerations. Indicators such as size spectra were considered to be robust and sensitive to changes in size, particularly loss of large organisms. Regulations such as maximum size limits were also considered to be easily understood and enforceable.
- Conservation of productivity was also considered to be a good objective because conserving productivity level might be made more operational than other things of higher priority. It was felt that size structure and biomass estimates are available for a number of key species.
- A number of general comments were also made on Indicators:
  - Indicator species must be well matched with the threat of concern.

- Management objectives must be matched by a good management system. One good example was the sandeel-kittiwake interaction in the North Sea.
- Good indicators for the management objectives need to consider natural variation in environmental effects and be able to distinguish them from anthropogenic effects.
- Long time series of information are very useful.
- We should build upon the single-species indicators that have already been well developed for many harvest fisheries. Additional single-species indicators could be added to the ecosystem and extended to ecologically-dependent species or those most sensitive to environmental impacts.

Discussion:
Rapporteur: Jean Munro

- In managing for pollution or other issues, examine different options including single species approach, otherwise experience may not be usable.
- Concepts and definitions may not be readily usable: go to actual issues and define objectives and indicators accordingly.
- Species diversity and productivity should be considered together

Breakout Group 2

Group Findings:

- The group expressed concern with the terminology. For example, what does ecosystem-based management mean? Is "ecosystem" a useful term? The group also noted the challenge of overcoming the divide between science and policy, and that the science must be transparent.
- The process of selecting objectives and indicators must involve all stakeholders. This process should be public, collaborative, adaptive, iterative, consultative, incremental and repetitive. Objectives will be set by community integrated management groups rather than by DFO. The science is one part of the process.
- The group recommended modifying the list of objectives as follows (two grand categories: productivity and diversity):
  - Instead of "The diversity of ecosystem types", The diversity of habitat types. We should be considering management within ecosystems, not across multiple ecosystems.
  - Species diversity.
  - Genetic variability within species.
  - Maintenance (rather than) "productivity" of directly impacted species.
  - Maintenance (rather than) "productivity" of ecologically dependent species.
  - Ecosystem structure and function.
  - Water quality: accept caveat that physical/chemical steady state variables be considered.
  - Added objective: human socio-economic benefits
- Finally, it was noted that the objectives should be defined temporally (in other words, they shouldn't be subject to annual re-negotiation).

Discussion:

Rapporteur: Jean Munro

- It was noted that "abundance" does not mean productivity, and the need for clarification on the definition of productivity. Workshop participants didn't specifically address what it was about species and habitats (and ecosystems) that needed to be protected. It was recommended that another term be used instead of productivity (e.g., biological characteristics).
- Participants were reminded of legal context and the goal that Canada is committed to as a signatory to the Convention on Biological Diversity. Canada has agreed to maintain various ecosystem types in the nation. Is it okay if we lose parts?
- Habitat is not synonymous with ecosystem; the latter term reflects the combination of structure and function, species assemblages, etc. Need to be clear on our definitions of "habitat" and "ecosystem".
- We should start with a process: adaptive, consultative. It is not the time now to define objectives but the time to develop a process to come to them.
- Human socio-economic objectives should be added. DFO has facilitator role and not responsible for all the actions
- Conserving ecosystem diversity means conserving subsystems or communities (eelgrass e.g.) and ensure that they remain in existence: you don't loose any habitat type.
- Maintain communities or integrated units and not the physical basis only.
- Words and definitions aside, we want to maintain all types of ecosystem or habitats i.e. units.

Breakout Group 3

Group Findings:

- The "diversity of ecosystem types" should refer instead to habitat types, this would emphasise links to landscape ecology and its associated indices (lacunarity, contagion, diversity, etc.).
- "Species diversity" is interpreted to include species of special concern [the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) lists]. Genetic variability within species; productivity of directly impacted species; and productivity of ecologically dependent species are accepted as valid ecosystem objectives.
- "Ecosystem structure and function" should be expanded to include "biological burdens" such as the incidence of parasitism and disease; functional diversity; processes; and inter-specific interactions.
- Water quality should include sediment quality.
- Assuming the above modified NPC ecosystem objective categories were sufficient to move ahead (a debatable point), the group then developed a list of threats common to all the above objectives (adapted from the biodiversity literature):
    - Continued permanent alteration of ecosystems and habitats; single events can also alter ecosystems (trawling temperate corals); cumulative impacts
    - The introduction of alien harmful species
    - Degradation of ecosystems from pollution and other factors
    - Global climate change and other atmospheric change (noting that there must be recognition of alternative states needed for baseline monitoring)
    - Non sustainable harvesting practices

  - Biological component of habitat degradation
- Categories of indicators emerge from the above threats and objectives, as follows: habitats; productivity of key species; representation of functional group; species of special concern.

Discussion:

Rapporteur: Jean Munro

- It was noted that the NPC list of objectives doesn't give an organizational framework. One needs a framework that structures what we want to protect, carefully forming and framing the different dimensions that we want to represent (comparison with economic frameworks).
- Developing a list of threats to ecosystem objectives may be a useful way to frame the development of indicators, but it follows the approach of issue-based management with all of its associated biases. However, in practical terms some managers fall back on issue-based management as a necessary evil. If issue based management is to be the operational model, then one must at least expend some effort to foresee what specific impacts are likely to occur (focus on cumulative impacts). No review has ever objectively demonstrated that issue-based management actually works worse than integrated management or other alternatives. In concept, integrated management sounds better than issue-based management, but the jury remains out on whether or not it produces better policy and management decision-making at the same or lower cost, and responds faster or better to conservation risks).
- A short debate ensued on whether the "threat list" approach used by this breakout group represented actual threats. Most seemed to agree that it was representative of actual present alterations to ecosystems. However, the list of ecosystem objectives alone could lead to the development of similar indicators.
- One participant noted the problems with a long list of indicators, objectives and reference points. The longer the list of attributes, the longer the debate about how many have to go bad before any action occurs (people gather behind their preferred version). To move forward, resource management tables will need to reduce the list to what's workable. For example, is everything proposed by this breakout group truly an indicator? How many indicators are effectively enough?
- In issue-based management, it is important to foresee what specific cumulative impacts are to come.
- Is everything proposed truly an indicator? How many? We need a framework that structures what we want to protect: carefully forming and framing the different dimensions that we want to represent (comparison with economy).

Breakout Group 4

Group Findings:

- The group spent some time on the issue of terminology. They noted the importance of agreeing on a common definition of "ecosystem". The group mentioned the need for a hierarchy of ecosystem definitions, and noted that the spatial scale of interest depends on the management issue to be addressed. The group also noted the potential confusion over the phrase "diversity of ecosystem types", and wondered if this referred to "habitat" and what definition of habitat should be used. It was felt that mapping or characterising ecosystem boundaries would be a useful exercise to clarify some of these issues.

- The group also raised the question of whether there should be a category of "management" objectives, and noted that since humans are a part of the ecosystem, there should be indicators that have some social and cultural significance.
- Two proposals were presented:
  1. Segregate objectives related to biological integrity from those related to maintaining productivity for economic gain (noting that goals will often conflict).
  2. Sub-divide objectives into Parts and Processes components then regroup the 7 NPC objectives. (The group expressed caution over using confusing language (e.g. the #6 objective - ecosystem structure and function - was referred to as eco-babble).

Discussion:
Rapporteur: Jean Munro

- Habitat type issue refers to a gradient definition : everything is critical habitat for fish. "Habitat areas of particular concern" should be used rather than "essential habitat".
- "Parts and processes" framework could be used at all levels of the hierarchy (genes, species, populations, etc.), but further clarification is needed on where "productivity" fits into this framework.
- After raising the analogy of economists' use of 12 key economic indicators, it was suggested that a more appropriate analogy was using a set of indices like family income and grocery cost index or poverty index rather than Gross National Product (GNP).

Breakout Group 5

Group Findings:

- Ecosystem Objectives:
  (1) Identify operational definitions of the ecosystems of interest (i.e. identifying societal values here is essential, consult existing statutes and policies to provide starting point).
  (2) Maintain the diversity of ecosystem types (as it is "today").
  (3) Maintaining the structure and function of these ecosystems i.e. objective 6. is an overarching objective that subsumes the rest i.e.
  - maintain species diversity, (as at time zero or with respect to an agreed upon reference period)
  - maintain genetic variability, (i.e. maintain natural genetic variability, evolutionarily significant units with species complexes, maintain integrity of naturally existing gene pools)
  - maintain productivity of directly impacted (by way of pollution or harvest) species,
  - maintain critical ecosystem linkages that control productivity and diversity within ecosystems (i.e. includes species that are indirectly affected or impacted by anthropogenic activities),
  - maintain habitat quantity and quality (physical, chemical and biological characteristics that support ecosystem structure and function).
- Simplify management of ecosystems by managing to proxies such as keystone species i.e. functional keystones (species that control ecosystem structure and function e.g. capelin), indicator keystones (species that integrate e.g. skates).

Discussion:
Rapporteur: Jean Munro

- Terminology should be clarified.
- Identify operational definitions of the ecosystems of interest. It was noted that identifying societal values is essential, as is the need to consult existing statutes and policies as a starting point.
- It will be important to translate objectives into publicly understandable terms.
- Can't just look at pieces, or we might miss important processes. It's often difficult to demonstrate processes that are at risk, even when pieces aren't. Remember, however, that is easier to motivate agencies, etc. to look into conservation of pieces (not too many processes at risk).
- Where does data availability enter into this discussion? Lots of data lacking. E.g. variability in meiofauna : little is known for not much sampled. However, if we agree on a hierarchy of objectives, and agree on indicators to use in measuring these, then need to determine what information is available and what needs to be collected.
- Pieces and processes to be cleared up : same problem as in International Council for the Exploration of the Sea (ICES) committees. We know the pieces: if we can protect the pieces what is left to protect processes? Now we miss some pieces in some ecosystems: this may have profound impact on processes. But it is easier to measure pieces so that lets go this way.
- There is a time element here: are we trying to go back to earlier times with complete processes?

Summary of Breakout Discussions

The workshop chairs briefly provided their observations on the breakout discussions. Overall, there did not appear to be a consensus on the National Policy Committee objectives, with many feeling that elements were missing while others feeling that there were too many objectives. It was evident that terminology was confounding some of the discussion, as was to be expected. There was an overall sense that the objectives need to be pragmatic and the framework understandable to the average person.

The workshop steering committee would consider the day's discussion and propose a new objectives framework on the following day. It later decided to do this in the afternoon after the manager's perspectives.

DAY 2: CASE STUDIES

International Case Studies

Ecosystem Considerations in Fisheries Management: Linking Ecosystem Management Goals with Ecosystem Research (Patricia Livingston)

Rapporteur: Don Cobb

Abstract:

As fishery management organizations move towards ecosystem-oriented management, there is a need to more clearly define the ecosystem management goals of the organization and the tools available to managers to attain those goals. Parallel to this must be an expansion of the scientific advice provided to management beyond traditional single-species stock assessment advice. Although there have been advances in multi-species and ecosystem modeling approaches, these approaches have not yet been completely embraced by the fishery management community. In some cases this is so because of the difficulties in validating these models and in other cases because of the lack of sufficient data and knowledge of the critical processes to develop an appropriate model. Progress can be made, however, in providing ecosystem advice to managers while we wait for these approaches to mature. The burgeoning GLOBEC and GLOBEC-like research efforts going on throughout the world, increasing emphasis on habitat research, ongoing trophic interactions work, and long-term monitoring of non-commercial species all provide useful information on ecosystem status and trends. Some of this ecological information can be used to gauge the success of various management schemes that have been put in place to meet ecosystem management goals. The North Pacific Fishery Management Council (NPFMC) has started to include some of this ecosystem research information in an ecosystems considerations document that supplements the traditional single-species stock assessment reports.

We have recently completed a revision of the ecosystem considerations document of the NPFMC. This document now contains many parts of a Fishery Ecosystem Plan recommended by the National Marine Fisheries Service (NMFS) Ecosystem Advisory Panel such as ecosystem status and trend information for many ecosystem components. It also has management indicators such as: amount of habitat closed to fishing, changes in the amount of fishery discards over time, and trophic level of the catch. This document provides a way for ecosystem research scientists from a variety of organizations to inform stock assessment scientists of their results and for managers to link management actions with ecosystem observations and ecosystem-based management goals. Future work includes the development of more quantitative management objectives and ecosystem indicators.

Presentation Highlights:

- The presentation focused on the Alaskan experience of linking ecosystem management goals with ecosystem research, describing the case study of the federally managed groundfish populations
- Their Goals are as follows:
  1. Maintain biodiversity
  2. Maintain and restore habitats of fish and prey
  3. Maintain system sustainability (human consumption and non-extractive uses)

4. (Maintain the concept that humans are part of the ecosystem (i.e. responsible for managing human behaviour in the ecosystem and tracking this)

- The framework used was described as Ecosystem Measures and Influences. The framework included two categories of indicators: Management and Status.
- Management Indicators are intended to:
  1. provide early warning of human effects
  2. track efficacy of previous management efforts
- Status Indicators: (attributes of the ecosystem) are intended to:
  1. link ecosystem research to traditional fisheries advice
  2. provide new understanding of ecosystem connections
- Three concepts (and associated indicators) have been used to assess ecosystem impact issues; i.e.:
  1. Predator/prey relationships
  2. Energy flow and balance
  3. Diversity
- The speaker summarised her talk by noting their experience in synthesising ecosystem research at various levels, communicating across levels, emphasising the development of indicators and monitoring trends, and their early efforts aimed at quantitative linking/prediction.

Discussion:

- A number of specific questions clarifying indicators were asked, as were questions on the multi-species models being used. It was noted that the data used was derived from surveys independent of the fishing industry.

Objectives and Indicators for Ecosystem-based Management: The Antarctic Experience (Andrew Constable)

Rapporteur: Jean Munro

Abstract:

The Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) was agreed in 1980 and came into force in 1982. Since that time, the Commission and its Scientific Committee has been focussed on implementing the ecosystem approach to managing fisheries encapsulated in Article II. By 1990, the Commission had agreed on quantitative formulations of Article II for target species and established a precautionary approach to all its fisheries aimed at ensuring ecosystem objectives are met despite the great uncertainties surrounding all the fisheries. The Commission has not yet interpreted Article II in an ecosystem context but recent work has begun extending Article II into this area in regard to the potential effects on productivity of dependent species.

Since 1986, the Scientific Committee has been working toward developing the CCAMLR Ecosystem Monitoring Program (CEMP) and how outputs of that program could be utilized in determining acceptable harvest strategies, including catch limits, open and closed areas and open and closed seasons. CEMP has aimed to investigate the potential competition between fishing for krill and the predators of krill by monitoring the overlap between foraging of predators and the fishing operations, changes in abundance of krill and its predators, changes in demographic

parameters of the predators and variation in the environment. This presentation will concentrate on the manner in which CCAMLR is developing its ecosystem approach to managing these fisheries and will consider (i) the types of effects fishing might have on the Antarctic ecosystem; (ii) the reference points currently used in CCAMLR, which are currently only directed at target species; and (iii) the parameters (indicators) being monitored by the CEMP. CCAMLR is not yet in a position to use the outputs from the CEMP in managing fisheries. Some difficulties remain to be overcome and these are discussed. The utility of CEMP is primarily governed by whether the monitoring program can match the large scale in which the fishing operations occur.

Background References:

- Constable et al. (2000) Managing fisheries to conserve the Antarctic marine ecosystem: practical implementation of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). ICES Journal of Marine Science
- de la Mare and Constable (2000) Some considerations for the further development of statistical summaries of CEMP indices. CCAMLR Science.
- Constable (in review) The ecosystem approach to managing fisheries: achieving conservation objectives for predators of fished species. CCAMLR Science

CCAMLR Article II: Objectives (Operational considerations for target species in parentheses)

- Maintenance of ecological relationships (Escapement)
- Maintenance of populations at levels that ensure close to greatest recruitment (Recruitment)
- Restoration of depleted populations (Escapement, Recruitment)
- Minimise risk of irreversible change (20-30 years)
- Rational Use: Harvesting of resources is sustainable (long term annual yield)

Operational Objectives, Reference Points and Decision Rules for Target Species

- Reference Point – median pre-exploitation spawning biomass
- Limit to safeguard recruitment (recruitment criterion) – 0.1 probability (or less) of spawning biomass falling below 0.2 of the median pre-exploitation spawning biomass
- Target Level to ensure escapement of target species for consumption by predators (predator criterion) – the median spawning biomass at the end of 20 years is 75% (or greater) of the pre-exploitation median (escapement of 50% for species considered not to be important prey species).
- Long-term annual yield is the catch which will satisfy both criteria.

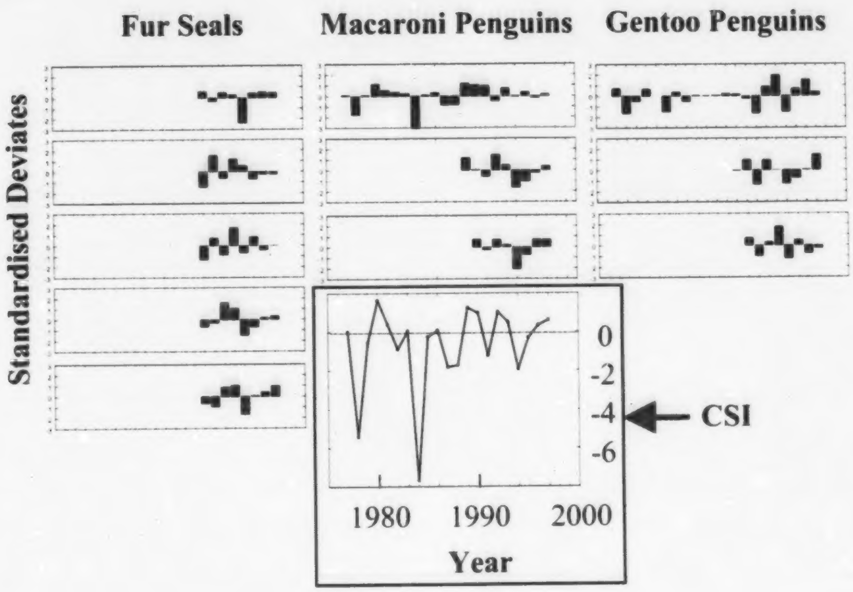
Reference Points for Food Webs

- Current Status of individual predator populations
- Current Rates of population processes
- Current Status of Integrated ecosystem statistics
- Current Production arising from fished species

Indicators and The CCAMLR Ecosystem Monitoring Program (CEMP)

- Categories (aim is to have a single index for each or at least very few)
  - Dependent Species (predators)
  - The Fishery (catch & overlap)
  - The Target Species (availability)
  - Environment
- Aims of CEMP
  - to detect the effects of fishing in sufficient time for fishing to be altered before irreversible damage is incurred
  - to detect long-term trends in the environment that require re-assessment of fishing controls
  - to distinguish between the effects of fishing and those of the environment

Composite Standardized Index (CSI) for predator parameters (and for use to summarize other categories).



- What makes an index work for management?
  - change in the index corresponds directly to changes in the state of the managed system
  - index is sensitive to fishing but comparatively insensitive to other factors
  - robust against uncertainties in the mechanisms that may potentially influence the index
  - unambiguous signals are derived in sufficient time for action to be taken
- Remaining Issues for the CSI:
  - Representativeness of species, parameters, sites
  - Sensitivity of predators to fishing (importance in food web; diet switching)
  - Sensitivity of process parameters
  - Matching the scale of monitoring to large scale of fisheries

- Future Tasks for CEMP:
  - identify important parameters for CSI
  - identify spatial and temporal scales necessary for monitoring
  - identify the types of decision rules that could be based on the index
  - differentiate between environment and fisheries
  - evaluate the CSI approach compared to productivity approach

Presentation Highlights:

- The management system within CCAMLR framework has two main components: the physical world and the management world. CCAMLR objectives can be summarised as maintaining ecological relationships (i.e. leaving enough prey species for predators); maintaining recruitment (i.e., population levels); restoring depleted populations; minimising the risk of irreversible change; and harvesting resources sustainably (which acknowledges that humans are a part of the system).
- The speaker noted the need to distinguish between attributes where there is lots of information, and those where there is little or no info, and noted the problem of having no information on an attribute that is key to understanding the system.
- Reference points, critical levels and decision rules arising from Article II: Shows the precautionary principle put into practice.
- The CCAMLR Ecosystem Monitoring System has four components (dependent species; the fishery; target species; and environment). The aim of the program is to:
  - detect the effects of fishing in sufficient time for fishing to be altered before irreversible damage is incurred;
  - detect long-term trends in the environment that require re-assessment of fishing controls;
  - distinguish between the effects of fishing and those of the environment (important for national jurisdictions to make this distinction because different action is required).
- Several issues were mentioned regarding the system, including:
  - Representation of species, parameters, sites.
  - Sensitivity of predators to fishing (importance in food web, diet switching).
  - Sensitivity of process parameters.
  - Matching the scale of monitoring to the scale of the fisheries.
- The importance of acknowledging uncertainty in the management system was also noted, as was the need for developing sound management procedures and rules for making decisions.

Discussion

- Could not one question the value of the index with respect to nonorthogonality of parameters? Already the index is composed of only three readily available parameters. If in addition these are not independent from each other, there is possibility that the various dimensions of the system be underrepresented. This issue should be further examined.
- The present indicators framework could be called a key species indicator framework. It is interesting that few key species seem to have worked efficiently as indicators of the whole system.

The South American Experience: Ecosystemic Considerations in the Management of Fisheries from the Patagonian Shelf Large Marine Ecosystems (LME) (Lobo Orensanz[2])

Rapporteur: Glen Jamieson

Abstract

The Patagonian Shelf LME supports two major industries based on the exploitation of marine resources:

- Fishing (industrial and artisanal)
- Eco-tourism (based on large colonies of marine birds & mammals)

Mandates and legislation pertaining in one way or another to ecosystem-related issues in marine resource management exist at every level (from international treaties to municipalities), but are largely nominal and ineffectual. Besides a few isolated cases in which specific ecosystem-related issues were addressed in the past, a major diagnostic opportunity was provided by the *Plan for the Integrated Management of the Patagonian Coastal Zone (GEF/PNUD)*. Five specific problems were identified:

- Incidental mortality of marine birds and mammals
- Competition between the fishing fleets and marine birds and mammals
- Bycatch of the industrial fisheries (mostly from trawlers)
- Environmental degradation caused by mobile gear
- Solid waste from fishing vessels

The organizers of the Workshop asked us to identify, from our own perspective:

1. The objectives for ecosystem-based management of marine systems. These were already specified by the organizers themselves; briefly:
   - Preserve the integrity of exploited ecosystems (diversity, structure, functioning)
   - Sustain productivity of the harvested resources (productivity referring here goods and services)
2. The associated indicators and how they may be defined and measured, and any relevant reference points

Alternatively to (2), we are encouraging an approach that:

- Creates mechanisms by which stakeholders, managers and scientists can work jointly to identify and address ecosystem-related management issues
- Emphasizes flexibility and common sense over aggregate indicators and/or reference points

Why? Because, in our environment:

- Indicators and reference points may be distracting, deflecting attention away from the real issues.
- They have a nasty tendency to take on a life of their own.
- They tend to be ambiguous, abstruse or unintelligible; specific issues are not

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[2] Based on a discussion held at Puerto Madryn (Argentina) with Guillermo Caille (Fundación Patagonia Natural), Enrique Crespo, Ana Parma and Pablo Yorio (Centro Nacional Patagónico.

- They put too much control of policy/political decisions in the hands of those who master intricate technicalities, *e.g.* the labyrinths of jargon

In our case, major prescriptions for action pertain to:

- Adjustments to institutional structures (avoid compartmentalisation of mandates)
- Implementation of regular channels to facilitate the interaction of stakeholders, scientists and managers
- Search for the appropriate incentives (not only for the fishers: also for managers, scientists and other stakeholders). In the case of fishers, these are primarily fishing rights:
  - In Chile: communal territorial fishing rights
  - In Argentine Patagonia: limited entry, based on a diversified resource base
- Empowerment of diverse stakeholders (awareness, extension, organization)
- Education of the general public

A specific case that we are currently addressing is the cascading effects of a crisis in the offshore ecosystem/fishery on the coastal ecosystems/fisheries:

- Under political pressure, boats inactive in the European Community's factory fleets entered the groundfishery of the Argentine Exclusive Economic Zone during the 1990s
- An inefficient (and politicised) management system allowed the collapse of the hake fishery
- Social unrest led to increased pressure on the coastal zone, where unsubsidised artisanal fisheries have struggled to keep their operations sustainable
- Under political pressure, provincial states consider extending new permits, inject subsidies for development, etc.
- Coastal ecosystems, including the bird and mammal populations that they harbour and the small-scale fisheries that they sustain, are under siege because of the deterioration of the shelf ecosystem.
- A strategic alliance between conservationists and artisanal fishers is required to create a "firewall" isolating coastal ecosystems (under provincial jurisdiction) from the crisis in the offshore industrial fishery (under federal jurisdiction).

In most study cases of ecosystem-related fisheries management the threat to ecosystem integrity comes from the serial fishing of components of the food web. In our case the cascade of effects between spatially adjacent ecosystems is mediated by a crisis in the social component of the fishery.

In the presentation, we focused on the southwestern Atlantic (the so-called Patagonian Shelf LME), although we have learned significant lessons from comparing it with the southeastern Pacific. Major differences between the fisheries from these two macro-ecosystems are outlined in the following table:

	SOUTHERN SOUTH AMERICA	
Coast	West/ Pacific	East/ Atlantic
Jurisdiction	Chile	Argentina & Falkland I.
Administration	Centralized	Federal (coastal zone under provincial jurisdictions)
Shelf	Very narrow	Extensive
Oceanographic features governing productivity	Eastern boundary current system Upwelling	Falkland Current, cold, flowing northward offshore, along the shelf-break Shelf fronts
Major industrial fisheries	Pelagics (horse mackerel, anchovy) Primary gear: purse seine Fish-meal oriented	Hake & squid Primary gear: trawling & jigging Oriented to the export of frozen food products Pelagics (anchovy, sprat) are virtually unexploited
Artisanal fisheries	Exclusive right to coastal waters Significant diving shell-fishery No trawling or dredging	No exclusive rights Diving restricted to few areas Mostly trawling for groundfish
Ecosystem-related issues	Ecosystem-based criteria for the management of TURFs	Interaction between fishing and marine bird/mammal populations

Presentation Highlights:

- The two major resource users are fisheries and ecotourism (the latter is growing relative to the fishery). There has been a fishery collapse in recent years, affecting most severely the offshore trawling sector.
- The Plan for Integrated Management of the Patagonian Coastal Zone identifies specific problems (see summary above).
- The Marine Protected Areas established along the coast are based on incentives associated with the local ecotourism industry, and fostered by conservationist agendas.
- Rather than focusing on indicators and how they may be defined and measured, the speaker suggested an alternative: create a mechanism by which stakeholders, managers and scientists can work jointly to address ecosystem-related management issues rather than expend a lot of effort on predetermined aggregate indicators. It was felt that indicators and reference points may be distracting, deflecting attention from the real issues; that they tend to be ambiguous, abstruse or unintelligible (whereas the issues are not). They also tend to put too much control of policy/political decisions in the hands of those who master intricate technicalities.
- Through their work they have tried to encourage: institutional structures and mechanisms to facilitate the interactions of stakeholders, scientists and managers; incentives (not only for the fishers, also for managers, scientists and other stakeholders); empowerment of diverse stakeholders (awareness, extension, organization); and education of the general public.
- How does science enter the picture? By channelling insights into working groups, identifying and analysing problems; i.e., by being a part of the process rather than providing indicators tied to reference points.

Discussion:

- In response to a question regarding the usefulness of indicators and objectives, the speaker responded that simple indicators are more useful than complex ones in communicating the implementation of objectives to all stakeholders. Indicators should be relevant, pragmatic and simple.
- It was also suggested that mapping indicators as opposed to abstract numerical indicators may be more understandable (e.g., point source data on a map).
- In terms of mapping indicators, the speaker mentioned their experience in participatory planning using locally based mapping exercises. These were found to be extremely important, incorporating information of local people and were useful for a variety of purposes (e.g., MPAs).

Observations from Australia (Campbell Davies)

Rapporteur: Glen Jamieson

Presentation Highlights:

- Dr. Davies gave a short presentation on some of the features of ecosystem-based management in Australia. The key principles in Australia's 1998 National Oceans Policy are ecosystem-based management, the precautionary approach, multiple-use management, stewardship and a multi-stakeholder management structure.
- An adaptive planning framework, specifying operational objectives and performance measures, is employed, followed by monitoring.
- Hierarchical spatial scales are used, from the largest LME, through the meso-scale (ecosystem sub-units or landscapes) to the operational scale. Assessment, reporting, and management response occur at each level.
- Thus far, the coastline is being considered at the meso-scale, with bio-regions defined. The next challenge is scaling up ecosystem-based management to the ocean level.

Discussion:

- In response to a question on whether it was useful to evaluate by bio-regions, it was noted that bio-regions serve a variety of uses (e.g., MPA planning).
- It was also noted that MPAs may be established by "special sites" rather than spatial representation, and that linking bio-regions to the management framework is important.

Canadian Case Studies

Incorporating Ecosystem Objectives Within Community Based Fisheries Management

(Mike Papst and Don Cobb)
Rapporteur: Robert Gregory

Abstract:
Settlement of Land Claims in Arctic Canada has mandated the development of co-management of Arctic fisheries resources. Co-management requires a high degree of community involvement as clients become partners in resource management. Experience has shown that community based fisheries monitoring can be an important element in developing effective fisheries co-management. If viewed as an opportunity, community based monitoring programs could become a vital part of incorporating ecosystem objectives into fisheries management. Having evolved from harvest monitoring, enhanced and complementary community fisheries monitoring programs in the Arctic already incorporate many of the indicators that would be present in an ecosystem based approach. Enhanced monitoring programs involve collecting basic biological information from primarily target species. Complementary monitoring programs link community based fisheries monitoring to larger research programs. Such complementary programs may involve linkages to telemetry programs, special sampling programs, or the use of non-traditional fishing gear. Enhanced and complementary monitoring programs can address ecosystem objectives related to diversity and trophic balance. An ecosystem based approach would also be consistent with the holistic approach many Arctic communities take to resource management. This presentation will review how community based fisheries monitoring has evolved and will identify some of the potential linkages between community based fisheries monitoring and ecosystem based objectives and indicators. Some recent examples of successful community based fisheries monitoring programs from the western Arctic are briefly discussed.

Presentation Highlights:

- In the arctic, fishing is largely for subsistence, and matters to people's daily lives. This economic context is crucial for ecosystem based management issues in the region.
- Land claims have established a co-management approach. There is a high level of community involvement. Community members are seen as partners, not clients, and so a high level of consultation is required.
- Monitoring is community-based. Management collects harvesting data and other info from communities, and incorporates traditional knowledge and the expert opinion of elders. This has been an efficient means of collecting data over a large area, and there is potential for expanding the monitoring system with further training.
- The main limitations mentioned for the community-based monitoring system: the system is currently limited to harvested fish and marine mammals. It is also difficult to obtain absolute abundance estimates.
- Community-based monitoring has provided researchers with a range of benefits including samples for genetic analysis of fish stocks, isotope analysis, stomach content analysis, etc.
- There are tremendous benefits to be gained by linking research and the community-based monitoring system. What is needed is:
    - consultation with Arctic communities;
    - documentation of existing projects (lessons and opportunities);

- pilot projects to link community monitoring to research projects; and
- evaluation of monitoring projects against ecosystem objectives and indicators.

Discussion:

- In response to a query on sell indicators to communities, it was noted the importance of involving them in the discussions, rather than simply imposing indicators.
- Traditional ecological knowledge (TEK) could be used if indicators are clearly identified and agreed upon by the communities themselves. It is important to look at the big picture and encourage the expansion of partnerships in new areas in consultation with the communities.

Development of Ecosystem-based Marine Management Objectives and Indicators for the Central Coast, British Columbia (Ian Perry, Colin Levings, Kris Hein and Fern Heitkamp)

Rapporteur: Joe Arbour

Abstract:

The BC Central Coast Land and Coastal Resource Management Plan (CCLCRMP) is a Provincial-lead initiative intended to establish direction for land and coastal resource use, management, and objectives. The objectives of this presentation are (1) to describe the process to develop ecosystem-based management objectives for the central coast of B.C; and (2) to describe the development of ecosystem indicators for this region that pertain to these objectives.

The planning process was stakeholder-based, in that objectives and strategies for this region were to arise from the stakeholders – the roles of government agencies were defined as technical and supportive, rather than advocacy. Numerous public sessions were held to gather information, identify key issues, and develop "picklists" of objectives and strategies. Out of this process emerged a series of objectives including restoration and maintenance of water quality and habitat, and recommendations for protected and actively managed areas. DFO participated in this planning process as part of its integrated coastal management and *Oceans Act* initiatives. DFO objectives at the table included conservation of productive capacity, fish stocks and their genetic diversity, MEQ, and critical habitats.

The planning process also identified several scientific and data issues, including how to define the Region's boundaries in marine areas; use of biophysical data to predict species distributions, fishing patterns, and biodiversity "hot spots", methods for selecting MPA's, availability of data.

A DFO project selected a subset of this region – Queen Charlotte Strait - as a pilot project in which to begin developing ecosystem indicators and indices that could be applied to the scientific issues and objectives of the CCLCRMP process. An important question is "How far can we go, and which indices and approaches might be developed, in using fishery-dependent data to assess ecosystem status and provide advice for management", since there are lots of fishery data but relatively few detailed fishery-independent and comprehensive surveys. This pilot study is examining commercial invertebrates in Queen Charlotte Strait from 1994 to 1998, a period of warm environmental conditions (note these conditions are not stationary among years). The general approach is to characterise the environmental variability, to analyse fishing data using GIS methods, to model and project preferred habitats, and to synthesize these data across

species using diversity, disturbance, and quantile-based indices, and colour-coded "quick" summaries ("traffic-light" style). The quantile approach produces relative indices based on the amount of variation within the region/sample being examined, but could be made absolute if specific reference points were defined. Two levels of spatial detail are being considered: the Statistical Subarea; and the fishing bed or tow location. These data are becoming more common with the use of detailed harvest logbook and/or on-board observer programs. Although designed as a pilot project to develop methods, the results can be used to resolve some of the scientific issues and help inform management objectives of the BC central coast land and coastal resource management planning process.

Presentation Highlights:

- The BC Central Coast resource planning process has involved the following steps:
  - Information gathering.
  - Key issue identification (through public meetings with DFO input)
  - Development of picklists, where all interests put forward. It was noted that government agencies acted as technical advisors rather than advocates in this process.
  - Map-based negotiation (e.g. zoning, special management areas).
  - Finalisation of recommendations.
- This multi-stakeholder process identified scientific issues.
- The DFO used the following objectives framework: "national" objective => DFO objective => indicators => definitions => reference points.
- Data was divided into physical, hydrographic and biological categories (indices), then colour-coded maps were created to show differences in sub-areas. Their aim: to synthesize the information and present it in an understandable format without over-simplification. Assumptions in the data were explicit. Indices were used to compare against CCLRMP objectives.

Discussion:

- Caution was advised in using fishery data, because it may not indicate a real environmental change (e.g., it may just appear that way when in fact the difference in the data is accounted for by a change in the way data was managed).
- The problem of calibration in indices was also noted, rendering quantiles extremely influential. Those who create them are aware of the complications while those who use them aren't necessarily aware of the complications and constraints that are built in.

Ecosystem Management in the Great Lakes: Thirty Years of Adaptive Learning (C. Ken Minns)

Rapporteur: Colin Levings

Abstract:

The events and experiences garnered by DFO's staff at its Great Lakes laboratory in Burlington are reviewed and lessons drawn for new efforts to develop and apply ecosystem management techniques in Canada's Oceans. DFO and other agencies led by Environment Canada and U.S. Environmental Protection Agency have been actively engaged in efforts to restore ecosystem health in the Great Lakes for more than 30 years. The history of successive Water Quality Agreements is reviewed alongside the evolution of the Ecosystem Approach concept that has occurred as thinking shifted from water quality management to integrated consideration of social, economic, and environmental factors. Examples of DFO's involvement in these events are described for three of the Areas of Concern where Remedial Action Plans have been developed and partially implemented. The three area have represented a different focus for DFO: habitat restoration in Hamilton Harbour, eutrophication and fish production in the Bay of Quinte, and fish habitat management planning in Severn Sound. The difficulties of obtaining broad consensus on ecosystem objectives are described with emphasis on the continuing dialogue today. The tentative efforts to develop Lake-wide management plans for Lake Ontario and Lake Erie are briefly described. LaMPs have been less successful, in part because of the difficulty of building sustained stakeholder interest and a shortage of science resources.

Lessons are drawn from this long history and experience: an integrated social, economic, and environmental approach is necessary; connectedness dominates making case by case issue management impossible; ecosystem management is mainly about managing people; and there is no need to re-invent the wheel in ocean management. Everything happening in oceans has already occurred with greater impacts in freshwaters. DFO should not ignore or waste the considerable experience and expertise established in its freshwater science programs as embarks on marine ecosystem management. In addition, adaptive management has emerged as the only viable technique for making progress, though most managers are reluctant to embrace the risks and uncertainties.

With regard to ecosystem management via objectives, indicators and endpoints. Objectives cannot be developed in isolation, take a long time to identify with multiple stakeholders, and there is still no consensus after 30 years in the Great Lakes. DFO must embrace the whole of ecosystem management and not try to restrict its focus to fisheries management in an ecosystem context. Indicators require sustained monitoring programs, monitoring programs that are vitally linked to research programs to ensure they remain relevant, and must be founded on scientific methods. Endpoints represent a particular difficulty for humans but must encompass ecological sustainability, give humans scope for choice now and in the future, and must use a time horizon much longer that stock-market or electoral cycles.

Presentation Highlights:

- After 30 years of concerted research and management effort in the Great Lakes, it is clear that ecosystem management has not been adopted by governments around the largest conurbations in Canada. "The dead canaries are still being ignored" in spite of a lot of thought about indicators, good monitoring programs, and substantial research. The goals of fishery agencies, for example, are still narrow and focus solely on production.
- Biodiversity management is a nightmare in these ecosystems because of extirpations and continual arrival and establishment of exotic species.
- Over the years, emphasis has shifted from management of eutrophication by phosphorus control (lake-wide scale) to concern about exotics and habitat loss and disruption (local scale). The latter is more problematic, but has been resolved to some extent by remedial action plans and specific control measures such as carp barriers.
- The performance of fish populations appears to be being used as an indicator of ecosystem function as it featured in more than half of the specific areas of concern.

- Twelve additional indicators ranging from biotic deformities to area of shoreline filled in were also mentioned.
- A key point made about objectives - there is still no consensus about ecosystems after three decades of work. Ecologists have to start using the clock of the long now to promote slower and better thinking and adaptive management.

Discussion:

- A participant wondered if the lessons to be learned by marine ecosystem managers from the Great Lakes experience were only those at the lake-wide scale.
- Another participant disagreed, stating that the destruction of the nearshore ecosystems at the land-water interface is likely to be repeated in the ocean as humans move to the coast.

Eastern Scotian Shelf Integrated Management Initiative (ESSIM) (Joe Arbour)

Rapporteur: Simon Courtenay

Abstract:

The Eastern Scotian Shelf Integrated Management Initiative (ESSIM) is presented here. It is the first Integrated Management (IM) initiative under the *Oceans Act* to address offshore issues. Under Part II of the *Oceans Act* DFO will lead and facilitate the implementation of IM in Canada's Ocean areas. The implementation will be ecosystem based and incorporate the precautionary approach, a collaborative approach as well as the principles of Sustainable Development .

The linkages to ecosystem objectives to integrated management plans are described within the context of the ESSIM initiative. The linkages are demonstrated through the use of a circle model that conveys the concept of acceptable and unacceptable conditions and the use of indicators and reference points to define the difference between an acceptable state and an unacceptable state for an ecosystem.

The objectives for the initiative are described. They embrace the conservation and responsible use of marine resources, the maintenance and restoration of natural biological diversity and the fostering of ecologically sustainable economic diversification and wealth generation.

A number of science activities are described that address the issues identified. These include an overview of contaminants, developing predictive models, identifying indicator species, completion of groundfish assemblage analysis, benthic habitat classification and biodiversity variability indicators. In addition some effort is going into the assessment of noise levels and the application of ecosystem models.

It is clear that the development of ecosystem objectives, clearly linked to integrated management Plan Outcomes will be essential to implementing integrated management on the Eastern Scotian Shelf. This therefore points to the need for a clear framework within which to develop those objectives and the indicators that will be required to assess progress.

Presentation Highlights:

- ESSIM is about linking ecosystem science to ocean management plans. ESSIM was the first offshore initiative under the *Oceans Act*, which set a new approach to oceans governance, including the Canadian Oceans Strategy; Integrated Management Plans; MPAs; and MEQ. The guiding principles: integrated management, sustainable development, precautionary approach, collaboration and the ecosystem approach. The vision: a process for effective management; striving for ecologically sustainable balance. ESSIM attempts to integrate the management of all activities in the eastern Scotia shelf region.
- Oceans and Coastal Management Plans consist of: defining management area; purpose, scope and legal basis; ecological overview/ health of the ecosystem; resources and uses in the area; identification and engagement of stakeholders; existing regulatory and management frameworks; principle issues, challenges and ecological threats; agreed goals and objectives (e.g., ecosystem, economic, social); collaborative processes and structures to be used in decision making; defined unacceptable outcomes and reference points; monitoring, evaluation and management actions as required.
- Oceans and Coastal Management tools: area-base management and planning (ocean-use zoning); MPAs; MEQ, etc.
- The aim is to define acceptable uses from the most constrained (MPA) through general and industrial uses within Ocean Management Areas (OMAs), and they use a performance line from the core (pristine) with reference points and triggers for management responses.
- Key themes: operationalising the precautionary approach; how to respond to uncertainty; monitoring capabilities and requirements; changes needed to existing governance processes (e.g., fisheries management, oil and gas); prioritisation of science research needs; cooperation between DFO Science and Oceans; focus on fisheries and the need to develop a common set of ecosystem-based objectives for all activities.
- Current research projects include investigations of: contaminants; baseline guidelines and standards; indicator species; habitat and species profiles; benthic habitat classification including biodiversity; traffic light approach; zooplankton and nutrients in the Gully; noise levels and potential impacts on whales in the Gully; GLOBEC; ECOPATH
- Despite the many research projects, there remains a need to link ecosystem science to Integrated Management

Discussion:

- Participants noted the usefulness of the ESSIM conceptual framework, particularly applying "acceptable" and "unacceptable" uses to differing zones.
- Who bears responsibility for defining unacceptable actions and how to "negotiate" appropriate response? First step in interacting with industries is to come to them with an idea of what "unacceptable" might be, rather than superimposing a whole new blanket regulatory regime over current one(s).
- Regarding risk management issues for government, depending on the issue, the public may be much more, or less "risk-averse" than the experts. For example, the public might be willing to accept more risk than the experts in the area of fisheries management but not in the area of for health issues. The challenge is how to bring technical information to these management issues to increase public understanding of risks involved.

Monitoring Pelagic Ecosystems in the Northwest Atlantic (John Anderson)
Rapporteur: Ian Perry

Abstract:

Within an ecosystem framework of fisheries science, the primary scientific question to be addressed is whether or not the ocean's carrying capacity is changing over time. When it does, then multiple states will exist within populations that require different realizations of their ability to produce young and to withstand fishing mortality. To detect change it will be necessary to establish long term observational programs (LTOP) monitoring key components of marine ecosystems. A fundamental question is whether changing productive capacity is driven by top down control by predators or bottom up production by plankton.

It is convenient to divide marine ecosystems into pelagic and benthic components. The pelagos is primarily where production occurs while the benthos is where this production is stored. Of particular interest to fisheries scientists is how annual production in the plankton is transferred to fish and invertebrates of commercial importance. Monitoring these changes over time and understanding the trophic linkages should be the guiding principles of our scientific research programs.

Recruitment of new fish into fishable populations is a primary input into single species stock assessment models. This is particularly true of populations recovering from overfishing or suffering the effects of excessive fishing mortality. Increasingly, it is being demonstrated for many species of fish that year-class strength is established relatively early in life. For Atlantic cod, year-class strength is established by the pelagic juvenile stage prior to settlement. For capelin, it is established during the larval or O-group stages shortly after their release and dispersal from beach and bottom sediments. Young of the year fish are the survivors of complex processes occurring during the first few months of life. We can regard their annual success, in terms of survival and growth, as a biological integration of these processes. When the annual response of similar across species lines then we begin to understand ecosystem responses when it occurs. Density dependent processes which effect survival during the multi-year juvenile pre-recruit period can modify year-class strength. We regard these as second order effects. Therefore, a key component of any LTOP would be the annual success of the pelagic juvenile (O-group) stages, before density dependent processes occur.

Perhaps the exception to the pelagic production/benthic storage model is the role played by multi-aged populations of forage fish. In the Newfoundland region, the primary forage fishes are capelin, sandlance and Arctic cod. Many people regard capelin as a keystone species, where important piscivore and mammal predators rely on the availability of capelin as their preferred prey. Interactions between species of forage fish and with their environment may be a primary monitoring goal of ecosystem processes, where Arctic cod populations dominate to the north, sandlance to the south and capelin in between. These fish are primarily planktivores where copepods are their most important prey. In this way, monitoring the abundance, distribution and condition of the dominant forage fishes would provide important measures of ocean carrying capacity.

A large-scale pelagic trawl survey was conducted 1994-1999 in the waters off Newfoundland. The primary objectives were: 1) to measure the distribution and abundance of pelagic juvenile cod; 2) to measure the distribution and abundance of larval and juvenile capelin; 3) to measure the entire pelagic ecosystem from plankton to forage fish, a size spectrum that spans three orders of magnitude. Results from this survey demonstrated an ecosystem response that began in the south in 1998 and continued to the north in 1999. This response was evident in significant increases in abundance, changing distributions indicative of spawning range expansions and increased fish condition. The range of species which increased included: Atlantic cod; haddock; redfish; American plaice; capelin; sandlance. The fish response lagged a warming ocean and increased zooplankton abundance indicative of more favourable conditions for spawning ad survival. The lagged response indicates that there was not a direct link between zooplankton and fish production.

Presentation Highlights:

- The basic structure for a monitoring program for the Northwest Atlantic should include: absolute estimates of abundance, biomass; biological responses, e.g. growth, condition; many species; their spawning components; and should recognise boundaries so that the monitoring program would sample beyond the boundaries of the system.
- In the pelagic system, ice provides the dominant physical forcing. Pelagic juvenile fish are the primary planktivores of cold water pelagic systems, which could be considered as "gateways" for regulating system functioning (or a "counting fence" in an analogy with salmon in streams). Cod and capelin (used to be) the dominant components of the system. But these populations have declined simultaneously with temperature, and it is difficult to detect cause and effect unambiguously. In addition, fishing produces confounding effects.
- Has there been a change in productive capacity over time? This might be answered by closing the area to fishing, or by observing young stages. The region was closed to fishing in 1993, and juvenile fish surveys have been conducted from 1994-1999, to sample this "gateway". The results are characterised by a strong north-south temperature gradient, and by similar gradients in zooplankton and nekton. Three regions can be recognised based on the distributions of nekton: Arctic (Arctic cod and squid); Boreal (capelin); Temperate (sandlance). But these "bio-regions" don't relate to Northwest Atlantic Fisheries Organization (NAFO) Divisions.

Discussion:

- It was asked if there has been much environmental variability during the study period? Yes. It was found that zooplankton responded quickly to this variability, but responses in nekton (mostly distributional changes) lagged by 1-3 years.
- Environmental variability present problems to defining management units with fixed boundaries, and to telling clients what they might expect in terms of species composition, etc. Perhaps there is a need to describe changes in terms of likelihood – e.g. what might typically be expected, and other conditions that might be expected "sometimes".

Approach for Selecting Objectives and Indicators of Ecosystem Health in Marine Coastal Communities (Jean Munro)

Rapporteur: Don Cobb

Abstract:

In developing MEQ ecological objectives and indicators, we are generally faced with two types of management goals, namely sustainable exploitation and conservation. This is especially true in the littoral areas of the Estuary and Gulf of St. Lawrence where major issues often focus on particular biological communities. This has led us to identify the community level as the centre point for developing one line of MEQ / Marine Environmental Health (MEH) monitoring plans applicable to the coastal area. Starting with the *Mya-Macoma* community, we plan to extend this approach to all important coastal communities.

Once the community is selected, we focus on the major issues affecting that community; for the clam community example, fisheries, pollution and climate change. For each major issue, we examine the various levels of ecosystem organization, that is the individual, population, community and ecosystem (biological), plus the chemical and physical components. Thus, although we focus on the community level, this approach is an ecosystem approach where potential impacts are sought throughout the system. At each ecosystem level, key properties that are normally used to describe the structure and function of that level, are examined to determine those which would be affected by the major issue. Next step is the search for indicators of these key properties. This step by step process allows a systematic examination of each ecosystem level and its properties.

Depending on the priority given to each selected property, criteria are set as to the level of accuracy, detail, economy, etc. that are to be met by the indicator(s) of that property. This is done through the examination of a table of indicators vs. criteria established from scientific literature and experience. Each indicator cannot be expected to fulfil the whole range of criteria. The full set of indicators should therefore be checked against the full set of indicator criteria so that the outcome is a balanced set of indicators.

For indicators to be useful and effective, we also need objectives and reference levels. Different approaches can be taken: comparison with historical data, with comparable but pristine areas, and with known gradient or successional trends. In setting reference levels, we plan to examine further the possibilities of using succession trends through succession experiments. General successional trends along spatial gradients and through time have already been demonstrated at the community level (Pearson & Rosenberg 1978). At the ecosystem level, a number of trends equivalent to regression in ecosystem development are expected in stressed ecosystems (Odum 1985), other studies have supported several of these trends. Succession trends are characterised by distinct peaks regarding abundance, biomass and trophic diversity that should allow for the setting of objectives, critical levels and reference levels.

In conclusion, this ecosystem approach applies to communities to find relevant indicators of ecosystem health. The approach prioritizes issues, ecosystem levels and properties. Using this approach, we hope to obtain the smallest possible set of representative indicators covering the

major issues and their possible effects. Objectives and comparison levels, set with reference to successional trend, are applicable throughout an ecological zone.

Presentation Highlights:

- This case study is an example of the development of successive plans and integration into other planning processes. Once a community is selected, the focus is on major issues affecting this community.
- The framework used related Factors (human, natural), Organization Levels (individual, population, community), Properties (condition, abundance, age structure, productivity, resilience, productivity, diversity, etc.), and Potential Indicators.
- The criteria for the choice of indicators included: cost effective data collection (also, reproducible and timely), the existence of data (historical and present), and its ease of measurement.
- Objectives and comparison (reference) levels were set as follows: Management Objectives (to satisfy or optimise); Reference levels (compared to historic data).
- A succession model was used at the community level as it is a generally demonstrated and accepted method.
- The experimental study set three levels of disturbance to provide benchmarks to set objectives, compare values of the indicators and provide alternative management scenarios.
- The approach was based on the following principles: economy (smallest set of representative indicators); prioritising; objectives and comparison levels set with reference to successional trend.

Discussion:

- It was noted that when choosing objectives for managing ecosystems, maximising biodiversity and maximising yield are very different: how should this choice be made? Objective-based management initiative mentioned the previous day might be useful in this regard (a set of guidelines are available).
- Spatial management options can address diversity versus productivity management arguments.
- It was cautioned that "maximising" biodiversity is not an appropriate term (for a management objective) as it can be misconstrued. It was suggested to use the phrase "sustain natural levels of biodiversity" instead.

Perspectives by Fisheries, Habitat and Oceans Managers on Case Studies

Rapporteur: Jean Munro

A Fisheries Manager's Perspective (Don Radford)

Presentation Highlights:

- As a manager, the speaker is concerned with changing current management and management planning processes to meet the goals in the *Oceans Act* – all within the limitations of the financial and human resources. The issues managers face are pragmatic.
- He agreed that 1) broad goals (such as "maintenance of biodiversity") need to be clearly defined; 2) it is important to take a long term view; 3) common language is needed in order

to include all stakeholders; and 4) it is important to be explicit about what is acceptable and unacceptable behaviour.

- It would be useful to have a common set of goals and objectives and indicators for the region so progress can be assessed.
- Since the *Oceans Act* was introduced, DFO is still struggling on a species-by-species basis as it moves to an ecosystem approach.
- Several important issues were noted:
  - In the Pacific, management must move to a more formalised and consistent approach;
  - the Salmon Management and Assessment managers need to engage in the rockfish program.
  - Fisheries interaction should be viewed on a broader scale.
  - It would be useful to form alliances and partnerships between managers and scientists outside the confines of the single species/single fisher framework.

Discussion:

- When asked about changes to the advisory committee structure, the speaker described experimenting with a number of approaches incorporating more stakeholders.
- In response to a query on the fishing industry's support of ecosystem based management, it was noted that communication was a problem and that the industry has not been appreciative of shutting down fisheries of specific fisheries for ecosystem reasons.

Another Fisheries Manager's Perspective (Daniel Boisvert)

Presentation Highlights and Discussion:

- Many comments were heard that resonate from a manager's perspective, including those about uncertainty and communication.
- For last 20 years, we have attempted to define "conservation", and now we are attempting an even greater challenge by defining "ecosystem management". It is worth noting that we are still struggling to define basic terms.
- Managers need a clear message and a toolbox for the field to be able to relate to those in the fisheries and others who have to understand what management is doing. This will help to encourage buy-in from fishers.
- While the presentations seemed geared to coastal people, the big problem is further out (trawlers). We need to be able to communicate the ecosystem based management message to them and gain their acceptance.

Plenary Session – A Possible EBM Framework (B. O'Boyle)
Rapporteur: Joe Arbour

Presentation Highlights:

- The previous evening, the workshop steering committee had met to discuss what had been learned thus far in the workshop and how best to proceed. It had been originally planned to send participants into breakout groups to discuss the case studies. However, it was considered more important to keep the participants in plenary to develop a consensus on the overall ecosystem objectives framework, so that discussion in the coming days of the workshop could focus on details within these objectives.

- To stimulate discussion, the steering committee had drafted the ecosystem based management objectives framework illustrated in Figure A, the components of which were based on the presentations made on the first two days.

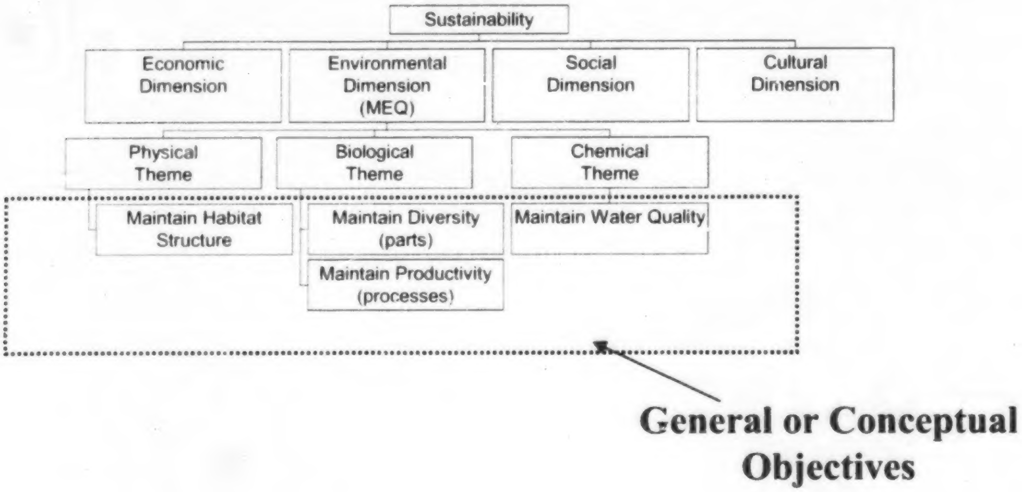
Sustainability
Economic Dimension
Environmental Dimension (MEQ)
Social Dimension
Cultural Dimension
Physical Theme
Biological Theme
Chemical Theme
Maintain Habitat Structure
Maintain Diversity (parts)
Maintain Water Quality
Maintain Productivity (processes)
General or Conceptual Objectives

Figure A. A draft Ecosystem-based Management Objectives Framework for Discussion Purposes.

- The framework presented a nested series of objectives, with increasing specificity as one moves down the levels.
- At the highest level, it considered conservation and sustainability as composed of economic, environmental, social and cultural dimensions.
- The environmental dimension, which would be the level to consider Marine Environmental Quality, was considered as composed of physical, biological and chemical themes. Under each of these, there would be conceptual objectives.
- Under the physical theme, the associated conceptual objective would be to maintain habitat structure.
- The biological theme would have two conceptual objectives – maintain diversity (parts of the ecosystem) and productivity (processes of the ecosystem).
- The conceptual objective 'to maintain water quality' would come under the chemical theme.
- Under each of these conceptual objectives would be additional conceptual objectives that add increasing specificity. For instance, under diversity, the objectives would consider maintenance of diversity at the ecosystem, species, landscape, population and genetics level (Figure B).

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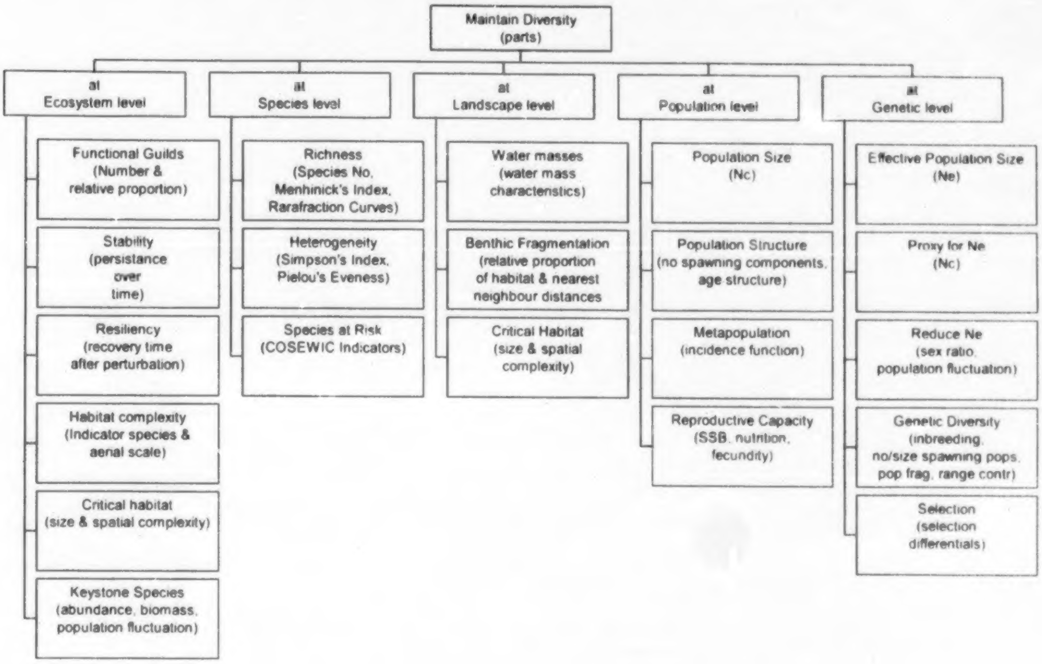

Maintain Diversity (parts)
at Ecosystem level
Functional Guilds (Number & relative proportion)
Stability (persistance over time)
Resiliency (recovery time after perturbation)
Habitat complexity (Indicator species & aenal scale)
Critical habitat (size & spatial complexity)
Keystone Species (abundance, biomass, population fluctuation)
at Species level
Richness (Species No, Menhinick's Index, Rarafraction Curves)
Heterogeneity (Simpson's Index, Pielou's Eveness)
Species at Risk (COSEWIC Indicators)
at Landscape level
Water masses (water mass characteristics)
Benthic Fragmentation (relative proportion of habitat & nearest neighbour distances
Critical Habitat (size & spatial complexity)
at Population level
Population Size (Nc)
Population Structure (no spawning components, age structure)
Metapopulation (incidence function)
Reproductive Capacity (SSB, nutrition, fecundity)
at Genetic level
Effective Population Size (Ne)
Proxy for Ne (Nc)
Reduce Ne (sex ratio, population fluctuation)
Genetic Diversity (inbreeding, no/size spawning pops, pop frag, range contr)
Selection (selection differentials)

Figure B. A Proposal for the Diversity Conceptual Objective, Characteristics and Indicators

- Then, under the most specific conceptual objectives, there would be associated characteristics, indicators and reference points.
- Characteristics were defined as those features of the ecosystem that, using best scientific information, are individually necessary and collectively sufficient to ensure conservation of the ecosystem. Characteristics most useful for ecosystem management are ones associated with indicators. Indicators are specific attributes of an ecosystem that are possible to measure and monitor, and whose values contain information about the state of some "characteristic" of the ecosystem require measuring.
- Under the ecosystem conceptual objective of diversity, characteristics requiring measurement might be stability, resilience, habitat complexity, and so on, each with an associated indicator or indicators.
- The structure of the productivity, habitat and water quality objectives are given in Figure C.

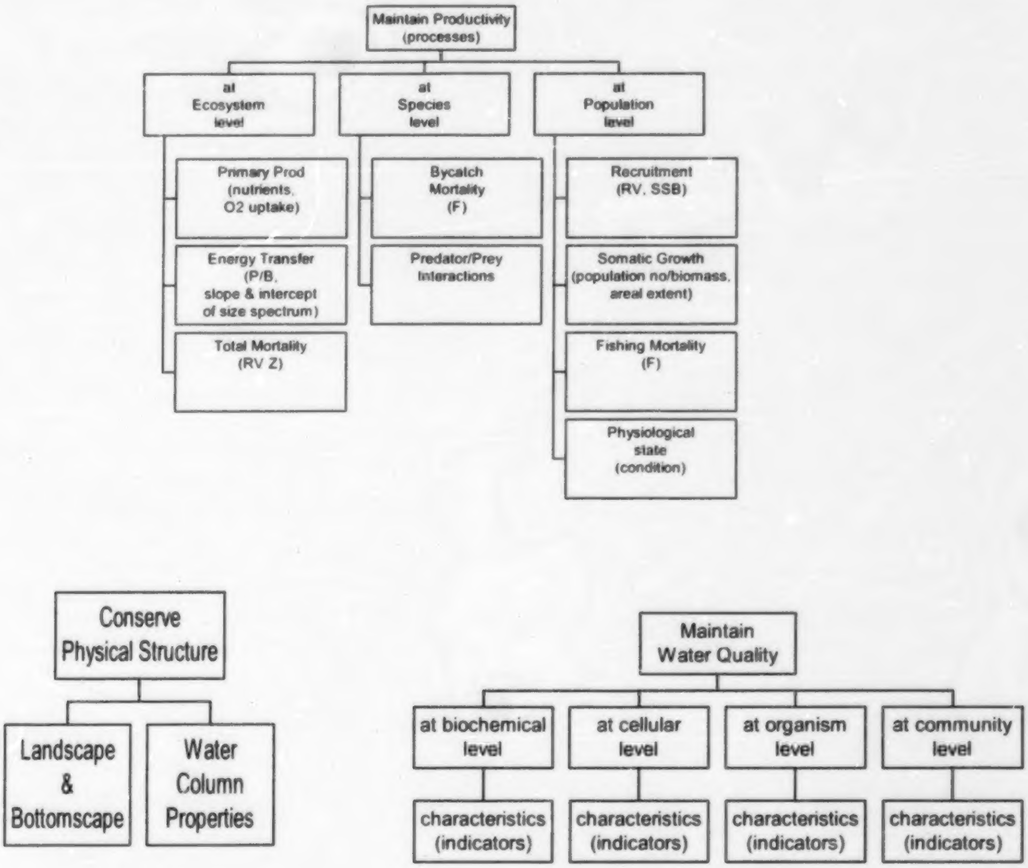

Maintain Productivity (processes)
at Ecosystem level
at Species level
at Population level
Primary Prod (nutrients, O2 uptake)
Energy Transfer (P/B, slope & intercept of size spectrum)
Total Mortality (RV Z)
Bycatch Mortality (F)
Predator/Prey Interactions
Recruitment (RV, SSB)
Somatic Growth (population no/biomass, areal extent)
Fishing Mortality (F)
Physiological state (condition)
Conserve Physical Structure
Landscape & Bottomscape
Water Column Properties
Maintain Water Quality
at biochemical level
at cellular level
at organism level
at community level
characteristics (indicators)
characteristics (indicators)
characteristics (indicators)
characteristics (indicators)

Figure C. Proposed Structure of Productivity, Habitat and Water Quality Objectives

- An illustration was then provided of how this framework would be operationalised in an Integrated Fisheries Management Plan (IFMP), using Scotia-Fundy offshore scallop as an example. In this illustration, the concept of state vs. response indicators, as used elsewhere, was introduced.
- The objective under the current IFMP is biological sustainability, with indicators being fishing mortality and landings. Ensuring that the IFMP would meet broader ecosystem – level objectives would require inclusion of indicators and reference points across a suite of objectives (Figure D), not just productivity, as has been the traditional single species management approach.

Scotia-Fundy Offshore Scallop

Objective	State Indicator / Reference Point	Response Indicator / Reference Point
Biological sustainability	Fishing mortality / Fmax, Size composition	Landings / TAC Meat Count / <33/500 gm

Scotia-Fundy Offshore Scallop
(Ecosystem-based IFMP)

Objective	Indicator / Reference Point	Indicator / Reference Point
Ecosystem diversity	Amount of area (ha) protected / 10%	Fishing location / Western Bank closure
Species diversity	na (e.g. no impact on SAR)	Na
Genetic diversity	No. aggregations / 80% of virgin	Fishing location / specified closures
Population prod	As current	As current
Species prod	Bycatch F / 0.02	Bycatch / specified amount
Ecosystem prod	na	na

Figure D. An illustration of Objectives, Indicators and Reference Points in an IFMP required to meet ecosystem-level objectives.

Discussion:

- Participants generally agreed on the need to keep the framework simple.
- There were some that suggested that the objectives should be developed beginning with issues. Others felt that it would be better to use an area-based approach rather than the current species-based approach when developing objectives, as it seemed to be in the IFMP example.
- It was clarified that the intent in the example was to take an 'Ocean Management Area' area approach, for which all single species IFMPs would adhere to area-based ecosystem-level objectives. All plans within an area, be they for fishing or mineral exploration, would adhere to these objectives.
- In setting up objectives, a stepwise process was recognized: from qualitative to quantitative; or from conceptual to operational; or yet from management style, to MEQ and MEH objectives. There were different points of view as to when in the process should indicators be chosen. Some felt that indicators could be set early while others maintained that they should come at the end.
- It was proposed to prepare an overall policy statement for Canada governing the framework, such as 'no more destruction of marine ecosystems', in which major impact issues would be listed, and with a 10-20 year plan to achieve this. In response, some noted that the problem is

more than about stopping structural damage. Other disruptions to the ecosystem also have major effects.

- Some felt that the term 'sustainable' might be confusing, although it may be useful within the framework. This raised the concern that the split of sustainability into four dimensions was not appropriate. Rather, based upon recent international dialogue, the sustainability of use should be considered separate from the conservation of resources, i.e. habitats and species. Sustainability of use would include the economic, social and cultural dimensions, while conservation would be restricted to the environmental dimension (Fgure E).

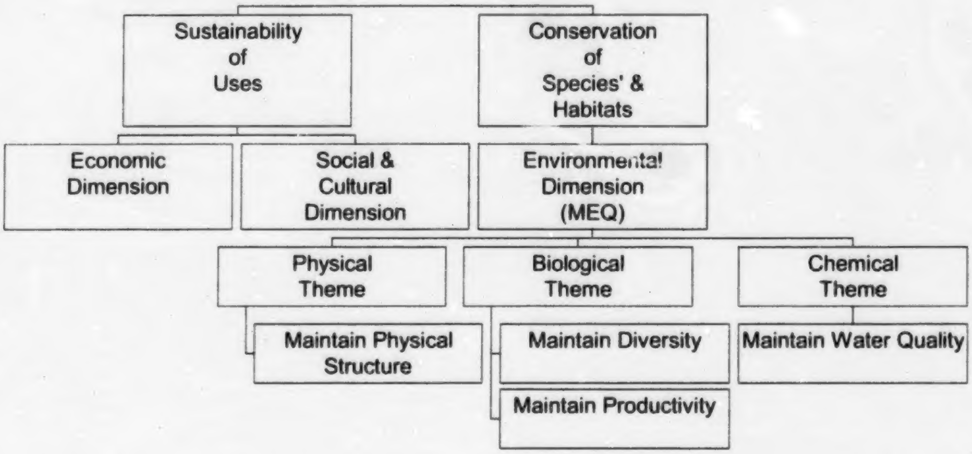

Sustainability of Uses
Conservation of Species' & Habitats
Economic Dimension
Social & Cultural Dimension
Environmental Dimension (MEQ)
Physical Theme
Biological Theme
Chemical Theme
Maintain Physical Structure
Maintain Diversity
Maintain Productivity
Maintain Water Quality

Figure E. Another Possible Ecosystem – Based Management Framework

- It was felt that the process of defining objectives could work as follows: an objective would be discussed until there was agreement at the conceptual level. There would be further discussion on its nested components at increasing levels of specificity seeking consensus. At some point, it will be possible to define a specific indicator associated with the objective. At this point, it becomes an operational objective. Picking the associated conservation reference point becomes a technical task once the indicator is chosen. (Note: its important to keep conservation and utilization reference points distinct – as with target and limit reference points elsewhere. Setting the utilization reference points is not just a technical task.)
- It was considered that for management purposes, setting appropriate indicators and reference points are critical.
- There was some discussion on the difference between a characteristic and an indicator. For instance, in fisheries, the characteristic might be spawning biomass (SSB), with the indicator being perhaps SSB or abundance of age five plus biomass from a model. If the reference point is defined on SSB, then the thing which triggers management actions is whether the probability that the current estimate of SSB (again from some assessment model with numbers at age and a maturity vector) exceeds the specified risk tolerance of being below the reference point. In that case it is SSB that is the indicator. On the other hand, if there are scientific reasons to distinguish 5+ biomass from SSB, then it is the risk profile of 5+ biomass relative to a reference point defined in terms of 5+ biomass that triggers action. A

reference point has to be defined in the currency of the indicator. The indicator – or a suite of them – should be sufficiently robust and sensitive reflectors of the characteristic to which some conceptual objective has been unpacked. This approach allows for a flexible and adaptable framework, with clearly identified logic and explicit linkages for unpacking through the various levels, a feature of the framework considered important.

- Within the environmental dimension, there was considerable discussion on the need for the physical, chemical and biological themes. It was further suggested that the seven Policy Committee ecosystem-level objectives could be more easily communicated if they were reduced to two: 1) to maintain diversity and 2) to maintain ecosystem structure and function.
- It was agreed that the themes would be removed from the framework and that the maintenance of diversity and productivity would remain as over-arching conceptual objectives, the latter referring the ecosystem structure and function. The terms 'parts and processes' were used inappropriately and would be dropped.
- There was agreement to combine the physical and chemical themes into one objective, the former being composed of water, currents and habitat, while the latter addressing water quality.
- There was considerable discussion on the stated objective for this grouping. Some suggested maintenance of habitat, but it was argued by some that one cannot separate physical, chemical and biotic factors from habitat. Habitat was not only physical. Others agreed that term 'habitat' does refer to the 'container' of the ecosystem and was appropriate for the objective statement.
- It was evident that habitat means different things to different people. No consensus on this could be achieved. For the purposes of the workshop, it was agreed to state the objective as maintenance of the physical and chemical structure of the ecosystem.
- Finally, it was evident that there needed to be consensus on definitions such as objectives, indicators reference points and so on. A few participants offered to draft text for consideration by the workshop.

DAY 3: ASSESSMENT FRAMEWORKS

An Overview of Assessment Frameworks (Brian Smiley)
Rapporteur: Robert Gregory

Abstract:

There are several frameworks commonly used by scientists and managers alike in Canada and elsewhere for assessing ecosystem health, in particular for monitoring, researching, assessing and reporting aquatic ecosystem trends. Based on Smiley et al (1998), this presentation describes those called stress(pressure)-condition-response models employed by interdisciplinary assessment practitioners over the past 25 years most often to assess and report on the state of the environment.

However these frameworks to be practical as well as effective must be implemented within an explicit step-wise but iterative process that includes goal setting, issue scoping, boundary and scale definition, valued ecosystem components, hypotheses generation, targeted research, routine monitoring, progress reporting, and communication to decision-makers. There is a special role for a common set of trend indicators (or metrics) that link human stressors, environmental

conditions and ecosystem responses. These model linkages become one of key challenges for scientific validation. Types of criteria used for validating linkages, appraising available data, and selecting indicators are summarized, as well as practical ways and means of applying them. Further arguments are given for additional basic but often inadequate assessment tools such as a common glossary of terms, hierarchical picklist of candidate indicators, lists of government and stakeholder contacts, annotated bibliographies and data catalogues, and so on.

Presentation Highlights:

- Several challenges were noted, including: scientific diversity itself, different data sets, authorities and stakeholders; unfamiliar cultures and traditions, levels of knowledge, time, energy and money; varying data quality and quantity; conflicting objectives and contrasting approaches (eco- vs. anthro-centric approaches).
- The speaker cautioned participants not to get caught up in the search for the "glass slipper" indicator – i.e., trying to fit a simple assessment approach, solution, or indicator to an inherently complex problem.
- It was suggested that generating indicators is like hunting for game: stalking to butchering and freezing is the scientists' work, but then others are tasked with processing the catch. Producing indicators should be an iterative process, not one that is of low priority. It's important to decide on the process for carrying indicator development process forward.
- Several steps were suggested to further the indicator development process: Choose boundaries; Scope the issues; Articulate the objectives and goals; Develop or select indicators to gauge progress; Conduct monitoring and targeted research; Report progress to govt stakeholders and public; Re-scope and revise. Other important "steps" or considerations were mentioned, including: Defining terms; Outlining a model (e.g. Holistic Ecosystem Model showing economic, environment, and social dimensions); Creating a comprehensive list of contacts, including all responsible govt, stakeholders; Preparing and making readily available maps and charts; Stating the questions to be answered (e.g., "state of the environment": what's happening, who cares, what do we do…?); Preparing "valued ecosystem components" (VEC) selection criteria.
- A proposed framework included the following components: human activities-> stress agents -> environmental conditions -> environmental effects -> societal response.
- The benefits of a visual and easily understandable framework were emphasised (i.e., this helps to communicate ideas to all audiences).
- Another helpful framework is the Stress-Condition-Effect Framework, which is composed of nested lists of attributes.
- Several criteria for selecting indicators were proposed: 1) data utility: available and timely, cost effective, geographic coverage, temporal coverage, accuracy and precision; 2) indicator relevance (defensible, representative, early warning, etc.); 3) indicator usefulness (understandable to non-specialists, relevant to goals, tied to targets and reference points); 4) politically acceptable. All are potential "deal breakers". The general rules of thumb for indicators were noted:
    - indicators must relate to goals and objectives
    - don't rely on only one indicator for decision making
    - indicator selection should be done using criteria that's been developed collaboratively

- indicators should be based on the best possible means, not just available means, which then allows data and research gaps to be identified.

Discussion:

- In answer to a query on simplify the process of indicator selection, the speaker suggested using a clear process, coupled with a framework to nest indicators and provide overall context or checklist.
- The difficulty of "selling" indicators was noted, as was the need to link monitoring to research.

Regional Ecosystem-level Monitoring and the Index of Biological Integrity (IBI) Concept Applied to the Southern Gulf of Saint Lawrence (Greg Klassen)

Rapporteur: Herb Vandermeulen

Abstract:

This talk presents some of the highlights of a research program conducted out of our laboratory at the University of New Brunswick (Saint John). This project involves the evaluation, development and implementation of an ecosystem-level monitoring protocol for (primarily) Kouchibouguac National Park (KNP). Currently in the first year of this program, we expect the evaluation and development phases to take approximately 5 years. What follows is a brief discussion outlining the motivation for this program and some preliminary results indicating potential benefits and future directions of the program.

Why ecosystem-level monitoring?

Much has been written on this issue. I will not delve into this subject beyond a brief account of some obvious advantages. Structurally, ecosystem-level programs (here we include community-level studies) allow for data collection and interpretation at various levels: species lists, indicator species, species richness, diversity indices, special/temporal structure, food-web structure, parasitological index of community connectedness. Similarly, at the functional level, one may investigate factors such as: respiration ratios, indices based on rates, rates of colonization/ emigration, rates of recovery of species diversity, rates of material cycling, biological/ecological regulation.

Why IBI's?

Many advantages of the IBI approach have been published in the primary literature (e.g., Karr 1981, Karr, et al. 1986, Liang and Menzel 1997, Fore et al. 1994, Deegan et al. 1997, Weisberg et al. 1997). Highlights of perceived disadvantages of previous methods, advantages of the IBI and our particular interest in this approach are listed.

Perceived shortcoming of previous measures

Chemical monitoring insensitive to flow alteration and physical degradation. Even for those effects they do measure, the effect on biological communities is only measured indirectly. Indicator species tend to be too specific. Prior indices such as diversity indices are insensitive to many "low-level" impacts.

Perceived advantages of IBI

Integrates information from individual, population, community, zoogeographic and ecosystem levels. An iterative procedure that preserves for evaluation the data associated with specific biological attributes. Can be used to screen large number of sample areas – allows for rapid feedback. Based on direct observation.

Beyond these observations, our lab has developed special interest in this approach for several reasons, including: its conceptually simplicity, analytical straightforwardness, transportability and robustness and, in particular the fact that it is easy to apply and teach and is relatively inexpensive to implement.

Applying the concept

It is recognized that estuaries of The Southern Gulf of Saint Lawrence Region are extremely important to the health of the regional ecology as well as communities that depend on those resources, such as fish and shellfish, depending on that health – far more important that their size would indicate. However, even basic understanding of biotic diversity and the long-term effects of human activity still elude us. Monitoring activities exists (usually associated with major industrial or construction activity) but tend to suffer from the shortfalls eluded to above. The direction in research as proposed here is in response to the need for a more inclusive, long-term monitoring program that is both sensitive to a large variety of potential stressors and easy to implement and interpret. We have taken a series of initial steps toward this goal. They include:

Review of literature

My co-author and graduate student in our lab is conducting an extensive review of the IBI-related literature to gather together and summarize important contributions to the field. Ultimately this review will serve as a basis for an "IBI-Cookbook" for the SGSL region. Highlights of this literature include: Karr 1981 – introduction of concept as applied to fish in fresh water. Karr et al 1986 – evaluation, identification of metrics, application. Liang and Menzel 1997 – evaluating scoring criteria for metrics. Fore et al. 1994 – statistical properties of IBI. Deegan et al. 1997 – first application of IBI to estuaries. Weisberg et al. 1997 – application of IBI to estuarine benthic invertebrates.

A natural reference model

Important to the development of such a regional monitoring protocol is the establishment of a "baseline" survey to understand natural variations and provide long-term, reliable reference sites against which to evaluate potential impacts. We consider the Kouchibouguac estuaries of KNP an ideal candidate for such a "Natural Reference Model". Basic biodiversity inventories are currently being carried out for fish, invertebrate (planktonic and benthic) and parasite communities as well as plant coverage and a series of abiotic parameters.

Developing and testing metrics

The next step is the identification of regionally meaningful metrics. A first steps involves using and modifying existing metrics from the literature (chiefly from Karr et al. 1986 and Deegan et al. 1997). Additionally, we expect to contribute to the efforts to increase the level of objectivity with which metrics are chosen and assessed (e.g., see Liang and Menzel 1997).

Assessing and testing the IBI

Before attempting to apply an IBI-based monitoring protocol on a regional scale (as we ultimately hope to do) we intend to test the protocol at several levels. First, we are collecting data to develop a testable model for the Kouchibouguac estuaries in a manner inspired by Fore et al. (1994). This, we hope, will establish a functional framework that will allow specific questions about impacts to be formulated as testable hypotheses according to the "Hypothetico-Deductive Method". For the IBI concept to become accepted within the scientific community, this step is essential. Second we will be testing the results from the IBI against "competing" methods such as "diversity indices" and, in particular, the Statistical Approaches to Community Analyses" proposed by many European authors and packaged as a statistical procedure (Primer vs. 5). Third we will be field-testing the IBI at a known impact site we have been monitoring in KNP for the past five years. Fourth, we will test the transportability/ robustness of the IBI by applying it to Prince Edward Island National Park.

Regional applications

In summary we are at the beginning of a research program that will make use of the IBI concept to develop in KNP a Natural Reference Model. This approach, it is hoped, will be used regionally as a long-term, low-cost and easy-to-use ecosystem-level monitoring program applicable to estuarine systems throughout the Southern Gulf of Saint Lawrence region.

Presentation Highlights:

- Chemical monitoring, diversity indices, and indicator species all have faults when applied to describe ecosystem health. The IBI is intended to be an improvement over those methods (Karr et al. 1986 is a key IBI paper). The speaker described the IBI concept applied to the Southern Gulf of Saint Lawrence.
- The IBI considers both structural and functional components of ecosystems. These are hierarchical and interactive. The IBI is expressed as a number, from 12 to 60 (poor to good). It is a composite multimetric, based on series of selected metrics (taxic diversity, tolerance vs. intolerance, trophic structure, individual health, respiration, productivity, etc.), integrating information from individual, population, community and ecosystem levels. Each metric individually evaluated and scored, then combined.
- The advantages of this approach are that it preserves for evaluation the data associated with the specific components. As well, it is conceptually simple, analytically straightforward, robust, transportable, easy to teach, and relatively inexpensive (can easily screen a large number of samples).
- Regarding transportability, it was noted that the IBI can't be readily applied across areas using the same metrics. However, fish and other organisms have been used for IBI work, (plenty of publications on this) – mainly fish and freshwater but also invertebrates and estuarine / marine systems. IBI has been widely used around the world (references cited).
- IBI's successful application depends on the involvement of academia, government and NGOs. It may potentially serve as a model for community-based monitoring.
- The author is attempting to create IBI indices for estuarine sites around Gulf of St. Lawrence. At the present time, the main reference site is in Kouchibouguac National Park (NB). The program examined fish (sticklebacks were important), macrobenthos (polychaetes especially important) and parasites along a salinity gradient up streams in the park. Beach seine

sampling was employed. In a focussed examination of a dock site species diversity did not change but relative dominance of mummichog and stickleback did (related to oxygen shifts).

- The speaker emphasised the importance of including parasites in the IBI. Parasites are a necessary and important part of normal ecosystems (structural importance and also a measure of ecosystem health).
- The speaker described the IBI concept applied to the Southern Gulf of Saint Lawrence.
- IBI considers both structural and functional components. These are hierarchical and interactive.
- IBI is a summary metric, based on series of selected metrics (taxic diversity, tolerance vs. intolerance, trophic structure, individual health, etc.), integrating information from individual, population, community and ecosystem levels. Each metric is individually evaluated and scored (5 if comparable to a healthy reference site, 3 if somewhat degraded, 1 if severely degraded), then combined. Therefore and IBI composed of 12 indicator metrics would range in score between 60 if all metrics were comparable to the reference condition, down to 12 if all metrics were severely compromised. The advantages of this approach are that it preserves for evaluation the data associated with the specific components. As well, it is conceptually simple, robust, transportable, easy to teach, relatively inexpensive.
- Regarding transportability, it was noted that the IBI couldn't be readily applied across areas using the same metrics. For example, because species assemblages and numbers differ latitudinally, the estuarine IBI developed by Deegan et al. (1997) for Massachusetts could not be applied to the southern Gulf of St. Lawrence. It would indicate depauperate communities in all sites.
- The speaker discussed the potential for including parasites in the IBI.
- IBI's successful application depends on the involvement of academia, government and NGOs. It may potentially serve as a model for community-based monitoring.

Discussion:

- While IBI was developed in freshwater systems, it is now being applied to estuarine systems. Does it have a larger marine application? The speaker responded that the concepts are applicable across systems.
- One consideration in its transferability is the need for basing the index on pristine systems (i.e. as reference points). IBI checks a variety of measures and selects among them to create an index. IBI must have a reference site to compare to (this can be a difficult problem in some systems). Conversely, IBI metrics must also be field tested on known impacted sites.
- While the IBI provides a single index, it may be useful at times to disaggregate the components (e.g. showing all the data in an AMOEBA format or other). The IBI can be "torn apart" to show the importance of the component metrics.
- One consideration in its transferability is the need for basing the index on pristine systems (i.e., as reference points).
- While the IBI provides a single index of "biotic integrity", referring to unimpaired structural components and their functional interrelationships, it may be useful at times to disaggregate the components. That is, the detail required for exploring and explaining changes in ecosystem structure and function is retained.

The Traffic Light Approach (TLA) (R. Mohn and P. Fanning)

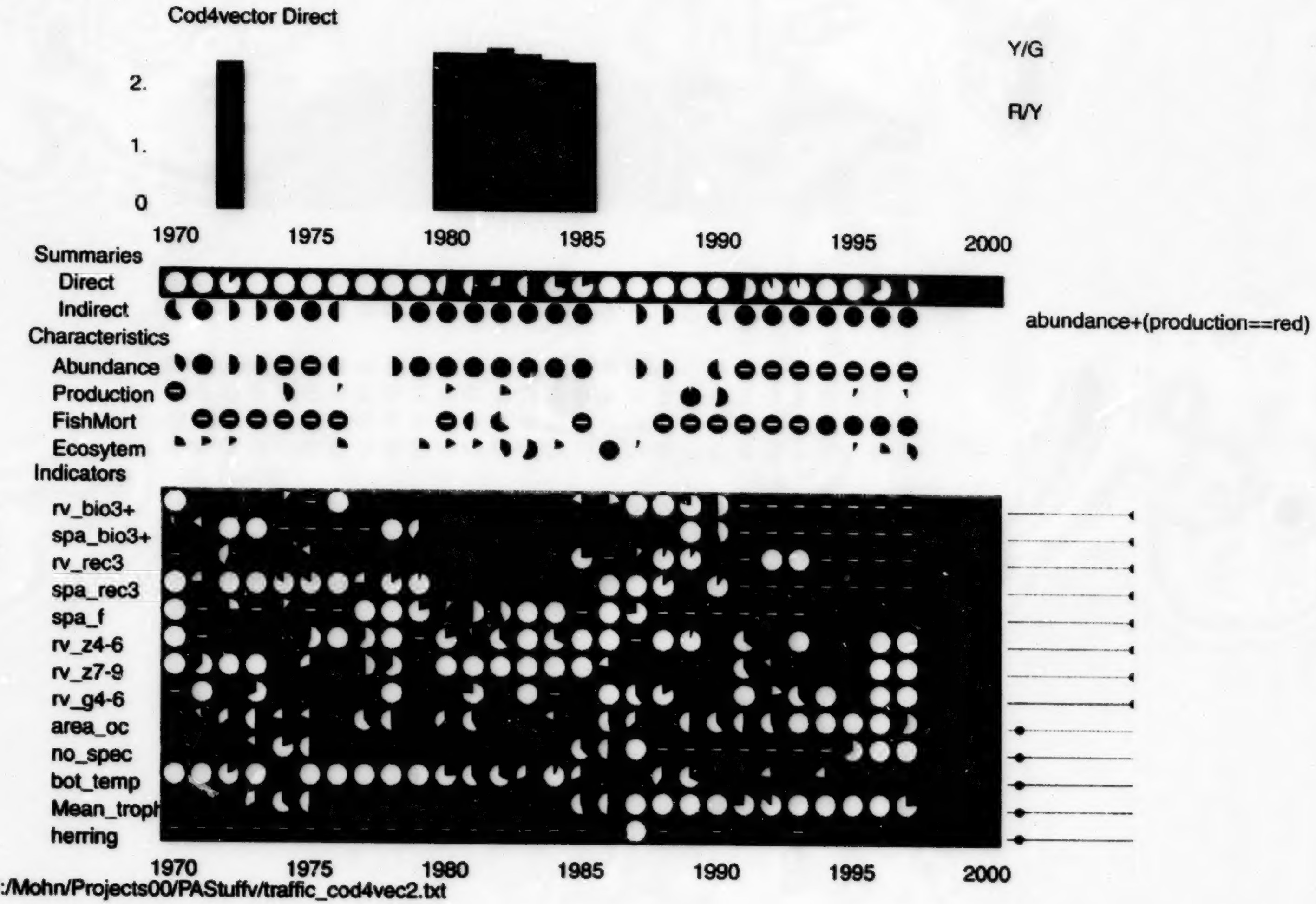
Rapporteur: Bob O'Boyle

Abstract:

Traffic Light Analysis/Approach (TLA) is a data-based method for the integration and presentation of resource status information. In this example the inputs, denoted indicators, are assigned to one of three colours. This conversion will cause a loss of precision. Other methods of conversion are under consideration which retain more precision through the analysis. Regardless of technique, conversion has the advantage of recasting disparate data into a common currency for presentation or subsequent analysis. In this example there is a requirement to define two cut-points which will slice the input into good (green), intermediate (yellow) or bad (red) regions. The cut-points may be based on analysis (e.g. F0.1), history (xth percentile) or perhaps other arbitrary criteria. In the following figure based on 4VsW cod, the indicators are in the bottom block and most of them would appear in a standard assessment document. Sequential Population Analysis (SPA) results are given as well as survey vessel indices of abundance and biological parameters. However, in traditional assessment documents the SPA biomass would be given much more emphasis than any of the others; here they are presented on an equal basis. The block labeled 'Characteristics' contains integrations of subsets of indices. Their purpose is to group similar indicators into composites for subsequent analysis. The uppermost block (Summaries) contains a 'Direct' summary which is a weighted average of indicators and an Indirect summary which is a model based result from the Characteristics.

Special emphasis was given to indicators reflecting ecological status. Some indicators are derived from ecosystem level consideration, such as mean trophic level. These are mixed with a variety of those derived from single species considerations but which reflect the impact of ecosystem processes on those species e.g. variations in natural mortality.

The method is still undergoing development and testing. Interactive and web versions have been developed. It has been used in recent Regional Advisory Process (RAP) proceedings and a validation workshop emphasizing indicators and integration is planned for this summer.



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Presentation Highlights:

- The TLA is a analytical method that brings together data from various sources which allows examination of system behaviour across a suite of indicators.
- One of its strengths is that it can incorporate information not easily accommodated by modeling approaches and thus it can be considered complementary to these approaches.
- The first step of the TLA is identifying those features or characteristics of the system desired for inclusion in the analysis. Then, for each characteristic, one or more indicators need to be identified.
- The key to the TLA is the next step – the assignment of "good, intermediate and bad" (green, yellow, and red) regions to each indicator. While precision is lost through this, what is gained is a common scaling for all indicators. This then allows summarization of the indicators for each characteristic and if desired overall indices of system behaviour. Such summarization of the information facilitates communication to managers and stakeholders of the state of a system in simple terms.
- While the raw data is processed, the principle of transparency is maintained – all inputs and values to the rescaled indicators are shown.
- Thus far, the TLA has only been used for single species stock assessment. However, an example was given which illustrated how the TLA could be used as an assessment approach in support of ecosystem – based management. It showed how indicators could be grouped into characteristics related to diversity and productivity, with sometimes the same indicator used in both cases.
- It was emphasized that the method still demands decisions on what are the important characteristics to monitor and what are the important cut points.

Discussion:

- The basis of cut points was discussed. In the example, these were based on history, although there is room in the method to base them on expert opinion.
- A concern was raised about the use of arbitrary limits. In the risk management context, is this the best way to communicate information for informed decision making? It was replied that the TLA communicates the information in a transparent manner and that it was a step in the process and not an end in itself. Decision makers would have the information on all inputs to the model.
- It was emphasized that while the method can process and display the information, it still requires solid science on the validity of the indicators. Do the indicators really measure the desired characteristic and how sensitive are they to change. All approaches depend on this.

Large Scale Questions, Small Scale Solutions: Juvenile Atlantic Cod in Coastal Habitats (Robert Gregory and David Schneider)

Rapporteur: Ian Perry

Abstract:

Ecological problems have strong spatial and temporal components. Logistical constraints often limit our ability to sample to small fractions of the area or time over which we wish to apply our inference. By necessity, we often extrapolate our conclusions beyond our data in order to

effectively manage resource use and measure the effects of such use on ecosystems. In short, we "scale up" to the spatial or temporal scale of interest from small areas or durations of measurement most often on a one to one basis relative to area – i.e., we scale isometrically. However, such isometric scaling is often inappropriate. Ecological variables often do not scale on a one-to-one basis across spatial scales, but instead scale allometrically. Our talk will be presented in two parts. First, we will describe the use of scale related measurements of abundance and mortality with eelgrass habitat in Newman Sound, Newfoundland. Second, we will discuss the implications of applying isometric scaling in ecosystems, where allometric scaling may be more appropriate.

In Newman Sound, Newfoundland, we have estimated density, mortality, and movement rates of demersal age 0 Atlantic cod and other species in nearshore habitats since 1995. We have also estimated habitat spatial area at several measurement resolutions ranging from 0.06 to 100,000 m^2. We have concluded from our work that ecological variables do not scale isometrically with habitat area or with map area (i.e., Euclidean area). For example, age 0 cod density increases not as a function of habitat area but as a function of habitat complexity – calculated as the perimeter to area ratio of eelgrass patches. Mortality rate, which intuitively should be expected to scale linearly with habitat area (i.e., mortality rate should be independent of habitat size), instead scales allometrically with habitat patch size. However, these relationships do form allometric functions, which enable mortality and density of age 0 cod to be calculated through a range of habitat spatial scales.

Spatial and temporal scaling issues are pervasive in ecology. As ecologists we tend to communicate our ideas at large scales, well beyond the scope of our empirical support. When isometric scaling is appropriate or the extrapolation beyond our data support is not too extreme, we can often do this without significant error. However, when we attempt to draw inferences across large differences in spatial scale or when scaling relationships are decidedly allometric, we do so at great risk of estimate error. As our thinking begins to move toward ecosystem scales, estimate errors may become more likely if principles of spatial allometry are ignored.

Presentation Highlights:

- Definitions of scale depend on the type of measurement. For example, there is the cartographic scale, whose extent is relative to "grain" size, and there is the ecological, which might be defined as the distance before some quantity changes by a specified amount. The problems of scale are not trivial. Ecological problems occur at very large time and space scales, but the ability to deal with these problems occur at small scales, e.g. days to weeks to months (or less when sampling).
- Juvenile cod provide examples. Cod are distributed on very large spatial scales in the NW Atlantic. But (for this presentation) they were studied in very local coastal environments.
- Eelgrass beds (preferred habitat for age 0 Atlantic cod) differ in structural complexity and pattern, thereby imposing small scale habitat heterogeneity. The experimental removal or addition of eelgrass dramatically changes juvenile cod density locally (10s of metres). Further, the mortality risk of juvenile cod due to predators depends on depth and habitat (decreased mortality in shallow depths and in eelgrass). However, risk of predation increases with eelgrass patch size, and density of age-0 cod increases with patch complexity.

- Therefore, how should one compare across spatial scale when rates of predation vary with scale? One approach is to look at eelgrass perimeter to area ratios at multiple resolutions (i.e., multiple grain size or scales). A relationship was found which predicts the area to perimeter ratio of eelgrass at different scales or resolution.
- With fisheries, the scaling problems are large, for example there is usually a need to scale up from haul to survey to stock – i.e. over different time and space scales with ratios of 3000:1. Imposed upon these scale issues is recognition that variance of many biological properties of marine organisms increases with increasing spatial scale. The presentation concludes that our problems are at large spatial scales, but the solutions (tools) are at small scales.

Discussion:

- There is an issue of homogeneity – at which scale can a system be considered homogeneous? And then at what scales can we sample? The problem is that this requires extended funding requirements to be able to monitor at large scales. We will need more money to do this – i.e. the dynamics of ecosystems are much greater than for individual stocks. We will not be able to solve ecosystem issues with the current manner of conducting studies.
- Perhaps we should propose large-scale experimental ecosystem manipulations. Yes, lessons can be learned from these experiments, e.g. from lake studies. Marine manipulations are more difficult or are impossible to control. However, there have been many "unplanned" marine experiments – we need to take advantage of these for evaluating ecosystem processes.
- The scalability to larger spatial scales may be much easier than scaling upwards in time, e.g. to decades. These are likely to require long-term commitments for resources.
- Simulation models, e.g. bio-physical models, may now help with these scale problems in space and through time (by using prognostic or time-stepping models). We are getting better at incorporating such effects into models, but there is still a need to test models at multiple scales. The "nested" scale model approach touched on in the talk was one example of how to do this. The approach could also be used at multiple temporal as well as spatial scales.

Managers' Perspectives on Assessment Frameworks

Rapporteur: Joe Arbour

A Habitat and Oceans Perspective (Marie-France Dalcourt)

Presentation Highlights:

- The speaker explained that in her role she is involved in integrated management (i.e., habitat and oceans). She applauded other speakers for looking beyond approaches tied to fisheries, since the ecosystem is about more than that.
- In order to communicate clearly with stakeholders, it is important to have a clear definition of ecosystems.
- Ecosystems must be considered at the large scale when possible (citing an example of sturgeon being tagged and travelling great distances).
- Socio-economic indicators should be considered in an ecosystem based management approach rather than kept separate. Often, environmental indicators can be translated into economics. Again, to improve communication with stakeholders, it is often better to put $ figures into the studies (so people can grasp the benefits).

- Approaches which allow for community involvement are likely more useful to the department.
- Since there are many differences between regions, a simple framework that is flexible to accommodate all is needed.

Discussion:

- It is important to consider how ecosystems are nested, even when management is done within geographic boundaries.
- From a Workshop on delineating ecosystems in the Georgia Basin, participants concluded that an ecosystem is what a manager wants to call it. The department should be careful in not spending too much effort on delineate boundaries.
- What are the social scales to consider? How do community scales and biological scales relate? Human scales are considered before biological ones.
- Defining an ecosystem boundary is a black hole. The ecosystem based management approach entails looking at ecosystem components and deciding what components/processes affect it.

A Fisheries Manager's Perspective (Chris Jones)

Presentation Highlights:

- For any given geographic area, a large number of management plans are operating which must be integrated. Plans include those for: 1) new and emerging fisheries (with monitoring and performance indicators for each); 2) increasing stocks; 3) stable stocks attempting optimum fisheries; 4) declining stocks and/or fisheries.
- Feedback mechanisms and dynamic indicators are needed.
- Remember that for the most part, the department is managing people, not ecosystems.
- Several reminders were noted in the application of Ecosystem Based Management Strategies:
  - Objectives must be pragmatic, easily applied and discernible (it should be mentioned however, that stakeholders are becoming increasingly knowledgeable).
  - Application requires not only simplicity but symmetry
  - Dynamic feedback mechanisms are essential.
  - Reference scales may be spatially and/or geographically dependent.
  - It is important to establish a range of objectives and monitoring indicators
  - The department must confer with stakeholders on the application of EBM.

A Regional Manager's Perspective (BC Central Coast) (Fern Hietkamp)

Presentation Highlights:

- New work is going on in the region on how *Oceans Act* can be implemented along BC's Central Coast.
- In developing and applying indicators, the public are involved in decision making, requiring new tools and appropriate structures.

- The Central Coast is managed through a suite of management plans and strategies that are being adaptively implemented; however, there wasn't a suite of indicators at the time of development to measure progress.
- The Central Coast could use a framework for assessing indicators and a suite of indicators that are relevant and useful (e.g., 3-4 indicators per management objective). The science should continue to "drill down' from the integrated plans (e.g., revising broad indicators if they aren't useful).
- There is considerable pressure for greater departmental transparency (from the public) and clear, understandable; scientifically based and workable indicators (from the government).
- Social and economic indicators are as important as biological indicators for the stakeholders – they will be looking for a balance when putting together plans.

Discussion:

- Why are social and economic indicators important? They will inform biological indicators and are not isolated. Who develops these social and economic indicators? A subsequent step to this workshop would be to look in more detail at these specifically, keeping in mind the department's need to be able to respond to public involvement responsibilities. Again, since the department is focused on managing people at most directly, it is important to bring in the socio-economic indicators/factors.
- There is a need to understand the incentives that people are operating under. Only by influencing these will the department have an impact on ecosystem management.
- There are several groups working in these areas (e.g. the "Genuine progress indicators" group working, Statistics Canada, Canada Mortgage and Housing Corporation).
- The technical community has a key role at two steps: first, in determining the "conservation bottom line" (which is non-negotiable). After this, there is the question of the different ways in which this bottom line can be met/exceeded. That discussion must involve more stakeholders.

Breakout Group Presentations on Framework Components

Instructions to Breakout Groups

On Wednesday afternoon, the plenary session came to a consensus with the conceptual objectives of ecosystem-based management, these being the maintenance of the physical and chemical structure of the ecosystem, its diversity and productivity. As well, the session on this day considered indicator frameworks. Workshop participants were to choose in which of the following four breakout groups they wished to participate

1. Physical & Chemical Structure (Joe Arbour & Herb Vandermeulen)
2. Diversity (Ian Perry)
3. Productivity (Bob Gregory)
4. Indicator frameworks (Simon Courtenay)

The chairs of these groups (indicated above) were to choose the rapporteurs from within the groups. The first three discussion groups were to unpack the major conceptual objective to the point of characteristics, illustrative indicators and reference points (RPs) for each objective to better define what the major conceptual objective entails, as well as recommendations for further work.

Regarding the Indicator Frameworks group, the IBI and TLA are two examples of integrative or aggregative assessment frameworks. Whenever we develop new tools for measuring aspects of environmental health, or changes in the state of the environment, we hope that they will be applicable beyond the geography and/or issue within which they were developed. However, even indicators that work only within a single stream may be of value if there is exists a unique reliable data series from past monitoring. Assessment frameworks attempt to measure the health of part of an ecosystem by comparing some indicator with a reference point linked to its potential. The potential may be based on historical information, as in rare cases where historical or pre-exploitation stock sizes are known. Alternatively, the potential may be measured from sites that are believed not to have been impacted by the anthropogenic influence in question. Here are some questions to address:

1. How are the integrative assessment frameworks presented (IBI and TLA) comparable? Do they provide useful assessment frameworks for ecosystem-based management? What are their strength and weaknesses? What other approaches are available?
2. The terms Marine Environmental Quality (MEQ) and Marine Environmental Health (MEH) have been used to connote overall properties of an ecosystem. What are the issues to consider when summarizing information across a range of ecosystem objectives to produce indices of MEQ or MEH?
3. Over what geographical scales should we be concerned with being able to measure ecosystem change? Are assessment frameworks scale-specific? What are the kinds of indicators and reference points that you would incorporate into the frameworks that are scale-specific?
4. What are the relative merits of historic versus synoptic (empirical) reference points? If historic reference points are important, how much effort should we put into developing and maintaining indicator time series data sets? How do we account for natural variability?
5. Are these frameworks that could be adopted for moving ahead MEQ nationally? If yes, is the way to do this through its identification under high priority funding envelopes such as ESSRF, or is there a better way? If not, do the deficiencies of any framework point to a better avenue for guiding and advancing MEQ research?

A small number of participants expressed an interest to form a fifth breakout group, chaired by M. Pakenham, to discuss some of the larger picture issues. Here, they will be referred to as the Alternate ecosystem based management Framework group.

Breakout Group 1 – Physical and Chemical Structure
Rapporteur: H. Vandermeulen

- Within the Chemical component of the framework, the group suggested that under the Objective, “maintain water quality”, components should include water, sediments, biota. Characteristics should consist of pathogens/algal toxin, harmful algal blooms, chemical conditions (nutrients, organics, dissolved gases, ammonia), ballast water – non-indigenous species (biological pollutants), sediment chemistry (PCBs, PAHs, D/F, Redox), health of biota (contaminant leads), bioaccumulation, contaminants sources, and biological effects. Indicators/Reference Points should include concentration in media, biochemical, cellular, whole organism, community (indicator species), human use; and end of pipe concentrations.

- Within the Physical component of the framework, it was suggested that the Objective would be to conserve physical structure. Components would include "landscape and bottomscape", and "water column properties". For both components, the following characteristics should be considered: landscape complexity/heterogeneity, coastal/watershed/wetlands/estuaries/ benthic sedimentation (sources, conduits, sinks), physiography/morphology, geology (source material), ice cover, distribution, tide, waves, fetch, currents, depth, biogenic structure (e.g., coral, eelgrass, kelp), human structures/garbage; fronts/gyres, stratification, fresh water runoff, and temporal changes (cycles). Reference Points would then refer to: No loss of critical structure (biotic or otherwise); reference points related to recovery/year; total suspended solids (% above background); Area (ha.) of land fast ice relative to base line; and Benthic (area of physical disturbance; e.g., through trawling, dredging, mining aggregate, log storage).
- Research needs (for both Chemical and Physical) were identified as: biological effect techniques; biogeochemistry; know background conditions (physical/chemical); inventory/baseline work; coastal marine benthic mapping; synthesis of information (multi-disciplinary); cumulative effects; predictive models; and monitoring.

Breakout Group 2 – Diversity
Rapporteur: H. Powles

- This group recommended replacing "diversity" with "Biodiversity", as it was seen to encompass the pertinent issues and provided a lead into the scientific and international legal research being developed around biodiversity issues. However, following the Rio and Jakarta meetings, one should probably use "Biological Diversity" for the distinction intended here, because both groups made the distinction between the broad concept of Biological Diversity and the more restrictive term biodiversity and its association with particular indices. The suggested goals for this theme, i.e. what we are trying to achieve, were:
  1. Maintain diversity of communities, species, populations within bounds of natural variability
  2. Lose no communities, species, populations through human activities
  3. Keep enough components to maintain natural system resilience.
- Therefore, the initial framework boxes need to be revised to focus on Communities, which are defined as "collections of organisms often associated with specific abiotic features". Since 'landscape' implies structures of communities, it would be appropriate to drop 'ecosystems' and 'landscapes' from this structure, and to assume that 'communities' encompasses ecosystems and their collection into landscapes.
- Species were considered appropriate in the context as intended in draft framework, and so were accepted as a component.

- Populations was seen to include genetic diversity, Evolutionary Significant Units (ESUs), and other biological attributes (ESUs were seen to imply the structuring of populations), and so Populations was defined to include maintaining the diversity of populations and genetics.
- The Break out group suggested the following as a framework for the 'maintaining biodiversity' conceptual objective:

Conceptual Objective	More Specific Conceptual Objective	Indicators	Reference Points
A. Maintain communities	1. Maintain trophic level balance – functional groups	a) size spectra b) FIB c) Effective number of species within trophic level	Now unknown – possibly based on undisturbed system
	2. Maintain habitat complexity	a) number of communities (assemblage analysis) b) Fragmentation (spatial pattern) of communities (ratio: disturbed/undisturbed)	
	3. Maintain rare and sensitive habitats	a) area of these protected/unprotected	
B. Don't lose species	1. Maintain rare species	a) k-dominance curve	Based on undisturbed
	2. Rebuild species at risk	Many tools developed: - abundance; - size structure; - condition; - growth rate; -	
C. Don't lose populations	a. Maintain population structure	a. Population size b. Metapopulation structure c. Presence/absence where they were before d. Available habitats occupied	
	e. Rebuild populations at risk		

Breakout Group 3 – Productivity
Rapporteur: J. Rice

- The group suggested focusing on the ecosystem level box and dropping species and population level boxes.
- A suggested conceptual objective was, "Do not cause the abundance/age-structure of any species to change enough such that its role in the food chain or ecosystem changes."

- In terms of Trophic – Nutrient Transfer, the following should be considered: nutrients, O2 uptake, primary producers, total removal by humans, primary production, slope of size spectrum, and secondary production.
- The group also recommended operational objective wording as follows, "maintain distribution of mean age of reproductive potential across species." It was considered that for management purposes, setting indicators and reference points are critical.
- The group spent most of the breakout session revising the conceptual method of identifying operational objectives and largely abandoned the "straw man" structure presented as a starting point for discussion. Much of the revised thinking is presented below.
- It was felt that the process of defining objectives could work as follows: an objective would be discussed until there was agreement at the conceptual level. There would be further discussion on its components, at each level of increasing specificity, seeking consensus. At some point, it will be possible to define a specific indicator associated with the objective. At this point, it becomes an operational objective. Picking the associated reference point becomes a technical task once the indicator is chosen. This approach was adopted by the workshop for all objectives.
- There was some discussion on the difference between a characteristic and an indicator. For instance, in fisheries, the characteristic would be spawning biomass, with the indicator being perhaps age five plus biomass from a model. This approach allows for a flexible and adaptable framework, with clearly identified assumptions for establishing the various levels, a feature of the framework considered important.
- It was not easy to come up with operational objectives for ecosystem productivity. Many of the boxes/entities on the working documents were considered interesting properties of ecosystems, but that was insufficient to make them suitable as objectives, or even as sources of objectives.
- At the ecosystem scale, there was eventually success identifying a solid objective for each of the three key aspects of productivity – primary production, trophic transfers, and total system mortality. In each case the objective might not be quite operational, but could be made so with appropriate analysis, possibly augmented by field measurements.
- PRIMARY PRODUCTIVITY:
  Objective: Do not cause primary productivity to vary outside the range of historic variation in primary production.
  Context: Unacceptable perturbations could be in either direction. Eutrophication, excess nutrient loading etc, could cause productivity to exceed historic levels, resulting in changes to species composition and trophic dynamics of succeeding trophic levels. For example, dredging might cause changes to water clarity or nutrient availability that resulted in depression of primary production, with less energy consequently available for higher trophic levels.
  Indicators: Examples include satellite measures of chlorophyll a. If there are no historic records of primary productivity, then judgements have to be made about the use of current measures as a threshold, median, or other benchmark.
- TROPHIC TRANSFERS
  Objective: Do not cause the abundance (biomass, size/age composition) of any species to become so altered that it ceases to play its historic role in predator-prey interactions.

Context: Unacceptable perturbations could be in either direction. This can become operational to the extent that one can estimate the predation mortality inflicted by a predator on its various prey, or the total predation mortality that a prey species can support. By "support", operationally it means without Z being so high that the prey species can only decline in abundance. Predators can become so abundant that the mortality they inflict on key prey causes a Z so high that their prey can only decline. Alternatively, predators could become so rare that Z of their prey becomes so low that given its intrinsic rate of increase (r) it could increase far beyond any historic observed abundance for the prey. Likewise prey can become so rare than with historic consumption rates, the Z will cause declines that are difficult or impossible to reverse.
Indicators – Information on abundance of key predators, and predation mortality rates suffered by key prey. Information on diets and metabolic rate will be very helpful, but life history parameters alone will be enough for first steps to be possible. A suite of predators and prey will be needed. Secondary indicators include slopes of size spectra and how the trophic pyramid is "sliced" (from the vertex downward, or from a side towards a lower corner) Many other measures are also conceivable. Density-dependent predator-prey responses may mean these indicators do not follow the true course of the ecosystem changes accurately. As a prey becomes rare, its predators may switch disproportionately to more comment prey, causing the actual Z the first prey species experiences to be lower than the estimates. Perhaps as abundance of a predator becomes depressed and its prey begins to increase in abundance, other predators switch onto the prey, so that its increase in abundance does not go beyond historic variation. Nonetheless each type of density dependent response moves the *ecosystem* to a different and new configuration, and one from which it may be hard to return to the previous "natural" (pre-perturbation) condition. In that case the indicators still gave reliable information about the proper direction of management actions needed to conserve the pre-perturbation ecosystem.

- MORTALITY
  Objective: Do not cause the distribution of mean generation times to be altered significantly
  Context: Mean generation time is a parameter easily calculated from a basic life table information (age specific survivorship and fecundity). A healthy community has some short-lived species, but also some longer-lived species, many iteroparous. As ecosystems are perturbed, life expectancies of at least some species must decline without compensatory increases in others, truncating the distribution of generation times. Strictly environmentally induced changes are likely to favour some species and not favour others, but leave the *distribution* of generation times more or less the same.
  Indicators: Calculating mean generation time for a species requires at least age composition data to estimate Z and partition it by age, and age-specific fecundities. If these data are missing, even the distribution of mean age of maturation is likely to be adequately sensitive. In any case, what matters is the distribution of a reasonable sample of species, ideally at several trophic levels, and not just the mean age of maturation of a single species (although see next bullet)
- At the species and population scales, we are in the domain of sound single species management. Even if we have not often produced stellar performance with single species objectives and indicators of productivity, we know a lot of what they should be. For example, we should conserve reproductive potential, not just standing stock biomass (SSB),

and we should conserve a broad age composition in the spawning biomass, not just a lot of biomass per se. Similarly, the goal of ensuring healthy recruitment (the conceptual objective) does not require just adequate reproductive potential, although there will unquestionably be operational objectives for reproductive potential or SSB. It also requires objectives with regard to preserving the important attributes of larval and juvenile habitats, and not placing the abundance of key foods for larval and juveniles of a species at unacceptable risk of decline

Breakout Group 4 – Indicator Frameworks
Rapporteur: J. Pringle

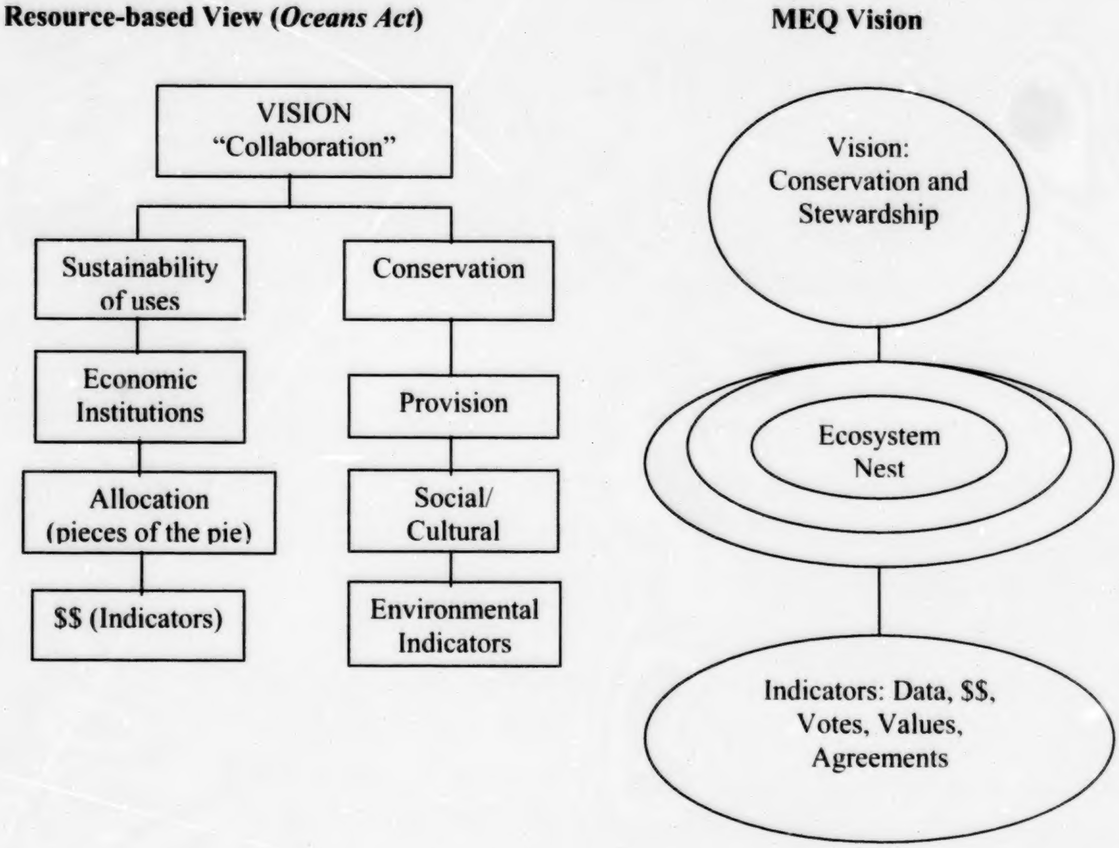
- The group suggested that rather than focusing on specific approaches such as IBI and TLA, it would be better to adopt a broader perspective in selecting appropriate indicators and suites of indicators.
- Top-down indices (IBI, CSI, TLA) are useful for management and for communicating with management but are ecologically insensitive; therefore, it is useful to distinguish between the data needs to be met (i.e., a managers' need or an ecological research question). Objectives drive the choice of indicators.
- It is also important to consider the IM context: objectives will come from the bottom up (e.g. from watershed management groups) and will be issue-based.
- Particular indicators must be tied to particular objectives (if some objectives are in conflict, then the unpacking process is not completed. It is why objective-setting should be an iterative process.)
- Objectives can be tiered as follows: short-term vs. long-term changes; major vs. minor impacts; insidious vs. obvious impacts; anthropogenic vs. other changes; etc.
- How specific do your objectives need to be for assigning indicators? In the CCAMLR and in the Bay of Quinte, they used four broad objectives and associated characteristics and indicators.
- The Pacific Region has developed an indicator toolbox that provides checklists of requirements and selection of indicators for monitoring once particular objectives have been set.
- Emergent properties: it has been suggested that multivariate frameworks can measure characteristics of ecosystems not captured by individual metrics. That is, an IBI may provide information additional to the individual metrics of which it is composed. However, this is only conjecture, and has not been demonstrated to date. It is a conjecture amenable to objective inquiry, and studies to date have not demonstrated the ability to get more out of IBI than was put in. The concept of emergent properties, and their measurement, evoked a fair degree of skepticism.
- Non-orthogonality of component metrics in multivariate indicators may render them insensitive to certain changes and hypersensitive to others. The IBI specifically favours redundancy of highly intercorrelated metrics.
- IBI probably addresses the ecosystem objective of diversity rather than other objectives.
- The group noted that there are different types of indicators: those relevant to managers and others useful for explanatory purposes (e.g., temperature).

- It is important to carry out preliminary work to assess indicator sensitivity before implementing a full-scale monitoring program.
- Regarding the strengths and weaknesses of IBI, its strengths were noted as follows:
  - Information from a number of different metrics may be more sensitive to a broader range of environmental degradation than individual "keystone" indicators
  - IBI is applicable to both vertebrates and invertebrates
  - Volunteers can be rapidly trained to collect data
  - Community stakeholders can be engaged
  - Useful in communicating with managers
  - Can be relatively inexpensive
  - Can be useful in identifying areas requiring additional research
- IBI's weaknesses were thought to be:
  - Its expense in particular applications
  - its lack of sensitivity as a diagnostic tool (though this may depend on how it is used)
  - Latitudinal specificity; i.e. the estuarine IBI developed for coastal waters of Massachusetts is not applicable to the southern Gulf of St. Lawrence. New metrics need to be developed; IBI is not an "off the shelf" indicator.
  - Reference sites are needed but are sometimes hard to find.
- The group recommended:
  - Assessing multivariate sensitivities by applying them to databases already available.
  - The first step in addressing management objectives should be to synthesize all information already available, including data not traditionally reviewed in this context (e.g., socio-economic).
  - The next step should be to assess the costs of NOT carrying out monitoring. Time series of data could be analyzed to measure the management consequences of not having had those data.
  - We should be explicit with clients; stakeholders and partners on our level of resource commitment to long term monitoring and consequent limitations on what advice we can provide.
  - Conduct pilot projects in representative marine environments to test approaches (IBI, etc.)

Breakout Group 5 – Alternate Ecosystem based management Framework
Rapporteur: C. Millar

- The group felt that the framework required an overall 'vision', which would then have objectives, actions (i.e. what should be done) and then indicators. Objectives should be set through a collaborative process involving all interests - through "institutions", which in turn are built through participation.
- Regarding the vision, it considered MEQ as including both conservation and stewardship, and not as had been proposed. They described this MEQ Vision as Conservation and Stewardship in the "ecosystem nested" framework, followed by votes, values, data, dollars and indicators (figure F).

- The group further noted the resource-based vision found in the *Oceans Act* was divided into "Sustainability of Uses" and "Conservation" chains. Sustainability of uses relates to allocation (pieces of the pie), which in turn implies economic institutions and therefore monetary indicators. Conservation relates to provision, which in turn implies socio-cultural institutions, leading to biophysical indicators. Thus, here, social and cultural dimensions would be considered under conservation, along with the environmental dimension.
- The group felt that the conventional view of sustainable development – i.e., interlinking circlings depicting environment, social, and economic components is not useful. Instead, they proposed 'ecosystem nesting', with social and economic components nested within environment. This follows from the reasoning that society and economy are dependent upon the environment. Social and economic decision-making that is isolated from the environment will destroy it.



Resource-based View (*Oceans Act*)

MEQ Vision

VISION
"Collaboration"
Sustainability of uses
Conservation
Economic Institutions
Provision
Allocation (pieces of the pie)
Social/ Cultural
$$ (Indicators)
Environmental Indicators
Vision: Conservation and Stewardship
Ecosystem Nest
Indicators: Data, $$, Votes, Values, Agreements

Figure F. An Alternate Ecosystem–Based Management Framework

DAY 4: BREAKOUT GROUP PROPOSALS ON ECOSYSTEM-BASED MANAGEMENT FRAMEWORK COMPONENTS

Breakout Group Presentations and Discussion

Instructions to Breakout Groups

The discussions of the previous day had gone quite far towards defining the sub-objectives, characteristics and indicators associated with each objective. However, the format of the feedback was very uneven with some groups identifying characteristics and indicators specific to each sub-objective, while others only listing these in general terms. As well, there was some confusion on what was a characteristic and what was an indicator. The discussions held in the subsequent plenary guided the groups to develop a more consistent set of sub-objectives, characteristics and indicators for each objective. Therefore, the breakout groups were reconvened under the same chairs to complete the tasks outlined the previous day. The results of their discussion were presented in plenary, where a consensus was achieved on the overall objectives/characteristics/ indicators framework. The group chairs consolidated this consensus view after the meeting was adjourned. This is reported in the main body of the proceedings

Breakout Group 1 – Physical and Chemical Structure
Rapporteur: Joe Arbour

- The group developed a physical/chemical table, which pulls together objectives, sub-objectives, characteristics, indicators, reference points and then operational objectives. They were also able to fill in the upper levels of the table.
- Issues identified by the group included the need for more research at the "characteristics" level, as well as further research on indicators and reference points.

Breakout Group 2 - Biodiversity
Rapporteur: I. Perry

- The table of ecosystem objectives, characteristics, indicators, reference points, and operational objectives developed by this group for the biodiversity objective (see above), was presented. This table was the result of cumulative discussions held over the course of this workshop. Justification for many of the decisions leading to this table are contained in the reports from Group 1 on Tuesday afternoon, and the Biodiversity Group on Thursday afternoon. Note that indicators and reference points provided in this table are only examples of possible criteria. It was agreed that the Goal for Biodiversity should be "to leave enough components (ecosystems, species, populations, etc.) to maintain the natural resilience of the system".
- Research needs were identified:
  - What is critical (obligate) and what is essential habitat? How does amount and spatial pattern of these habitats vary with the numbers of species, sizes of populations, etc.?
  - Efficient and effective mechanisms for implementing the operational objectives need to be developed;

- Population dynamics of representative species of functional groups need to be studied;
- Species inventories and taxonomic identifications – i.e. what is present, and how to identify them;
- Identification of "keystones", i.e. sensitive and "controlling" components;
- Reference points for indicators;
- Pilot projects need to be undertaken to further develop these tables below. To test various indices, and to move to operationalise these concepts.

Breakout Group 3 - Productivity
Rapporteur: J. Rice

- The group has developed a structured approach to addressing productivity (rather than the detail that fits in the boxes; i.e., actual objectives and indicators.
- The Productivity Approach: start with conceptual level objectives, then unpack to further and further specification and detail until a point is reached that is measurable. This measurable point would be called a "characteristic". Next, list everything needed to measure the characteristic. This would become a list of "indicators". When the characteristic is defined, identify its limits using reference points.
- To unpack trophic transfers: Begin with a major conceptual objective, then divide into aspects of predator and prey, noting attributes until one arrives at "characteristics" to be maintained (the "aha" stage!), which in turn drive the indicators. At this point, analyse data, run models, and conduct sensitivity tests, and then identify reference points. From this, operational objectives may be set to guide management decision-making.
- Approaches such as IBI, TLA, etc should be included in the productivity approach diagram. Examples would also be useful to include.
- This approach is similar to Antarctic approach, and has proven to be a valuable process. It was recommended that the number of features be limited (i.e., leave out the detail).
- The general response was that all groups could be put into the productivity approach diagram, and that it could be made site and species-specific.
- it was noted that the approach allows for one operational objective to be relate to a number of characteristics (i.e. chains don't necessarily lead to unique issues).

Breakout Group 4 – Indicator Frameworks
Rapporteur: H. Vandermeulen

- How are the frameworks presented (i.e. IBI, TLA) comparable? The two approaches are comparable in their construction and objective, namely synthesizing information from several indicators into a single or at least fewer summary indicators. However, their applications have been different and the two approaches differ in how indicators are selected. Some participants suggested that it might be clearer to refer to IBI and TLA as methods for producing indicators rather than frameworks.
- Do IBI and TLA provide a legitimate assessment frameworks for ecosystem-based management? IBI is reported in over 200 peer-reviewed publications covering a variety of terrestrial and aquatic ecosystems. A very few of these publications deal with marine

ecosystems. However, J. Karr – IBI's developer – sees no reason that it cannot be applied to marine ecosystems and has a MSc work doing just that in the coastal environment of Puget Sound at present. B. Smiley reported also that faculty at Royal Roads University (Victoria) are looking at IBI applications. Cliff Robinson (Parks Canada, Vancouver) is looking at an application of IBI in Pacific Rim National Park. PAPRICAN – a research organization for the Canadian pulp and paper industry – carried out a comparison of IBI and the sentinel fish survey required for the Pulp and Paper Effluent Regulations – Environmental Effects Monitoring Program in Quebec and is presently analyzing the results for publication. Greg Klassen is testing the sensitivity of IBI, relative to other approaches, in Kouchibouguac National Park, NB. That said though, participants were not all convinced that IBI/TLA were superior approaches to keystone or sentinel species in all instances and that these other approaches should be considered on an equal footing for now.

- What are the strengths and weaknesses of IBI and TLA? Strengths and weaknesses were discussed to some degree yesterday so this was not pursued today beyond noting that the derivation of a single number representing biotic integrity was both a potential strength in presenting a "red flag" for managers, and weakness if underlying structure is not examined. It was noted that IBI provides specific direction on the kinds of indicators likely to provide a useful signal of ecosystem change. Individual metrics may be easier to understand than composite metrics but managers and stakeholders are often more interested in the overall questions: How healthy is this environment, and is it getting better or worse? It will always be important for the scientist/biologist to be able to explain the output of the monitoring program to the managers and stakeholders.
- What other approaches are available? There are lots of other approaches to designating indicators and synthesizing their information, including AMOEBA, MDS and so on. Some approaches such as DELPHI can even be applied in data-poor situations. Participants of the discussion group were not sufficiently knowledgeable about IBI or TLA to recommend these over other approaches, but felt that IBI and TLA had sufficient merit to be tested against other approaches. It was noted that simulation modeling and non-quantitative methods such as DELPHI had a role to play in particular situations.
- What are the issues to consider when summarizing information across a range of ecosystem objectives to produce indices of MEQ or MEH? This question was not discussed by the participants, beyond noting that issues to be addressed at any IM table will be those presented by the stakeholders. It is within the IM framework (e.g., a basin-management group) that management objectives will be established and associated MEQ/H criteria, indicators, reference points and monitoring programs will be designed. That is, management will be explicitly objective-driven.
- Over what geographical scales should we be concerned with being able to measure ecosystem change? We are concerned with measuring change over the scales of parts of estuaries all the way up to Ocean Management Areas such as the Gulf of St. Lawrence, Bay of Fundy, Georgia Basin and beyond.
- Are assessment frameworks scale-specific? Participants felt that there was nothing inherently scale-specific in the IBI or TLA and that their principles should be applicable across scales though their component indicators would be scale and issue specific.
- What are the kinds of indicators and reference points that you would incorporate into the frameworks that are scale-specific? Discussion of scale-specific indicators and reference

points was considered to be beyond the scope of the present discussion except to note that reference points were easier to establish and interpret for individual indicators than for composite indicators.

- What are the relative merits of historic versus synoptic (empirical) reference points? It was felt that specific, contemporary reference points might be too restrictive in some cases. Both the IBI and TLA can accommodate either a historic or a synoptic reference point (i.e., indicators measured contemporaneously at an unimpacted reference site) depending on the questions being addressed by the monitoring program. Concern was expressed that a single reference point might not work well in multi-species models. Also, as illustrated in Jean Munro's talk on monitoring littoral bivalves in the St. Lawrence estuary – successional stage may also be used as a reference point.
- Are these frameworks that could be adopted for moving ahead MEQ nationally? Yes, these frameworks could be adopted for advancing the MEQ file nationally but not in isolation. Rather, the approach being pursued by G. Klassen in Kouchibouguac Park NB seems to make most sense: namely to collect data sufficient for constructing the IBI/TLA and for carrying our other analyses of the data (e.g., MDS, PCA etc.) and then to compare the information generated by the different approaches. Questions to be addressed include: 1) does the IBI or TLA approach generate useful information additional to that of its component metrics? 2) Sensitivity: is the IBI/TLA approach more or less sensitive than other approaches in detecting environmental degradation; 3) Ambiguity: can the IBI/TLA arrive at the same overall assessment through different combinations of component indicators – and if so – is this a concern for interpretation and utility by managers?
- Is the best way to proceed with pilot projects to identify them as priorities under DFO's high priority funding envelopes such as the ESSRF (Environmental Sciences Strategic Research Fund) or is there a better way? The DFO strategic funds generally will not fund projects for more than 3 years and a test of integrative frameworks would likely require 3-5 years so there is a logistic issue to be resolved here. Participants liked the idea of comparing multimetric framework approaches in pilot sites - perhaps one on each coast for example (e.g., GOSLIM; Georgia Basin; Maniquogan; Mactaquac Estuary). Criteria for selection of pilot sites might include: 1) IM plan in place with objectives established; 2) MPA sites; 3) identification of a major issue; 4) abundance of data available for modelling/simulation as a first step; 5) presence of ongoing initiatives and external partners for collaboration (e.g., universities; Parks Canada).
- It was suggested that simulation testing be added to the pilot site approach. From the Antarctic experience, it was noted that their case studies were deliberately selected to cover a range of conditions (from poorly understood to well-understood components, small to large, etc.).
- A five-year timeframe is useful, but progress should be demonstrated within five years.
- One key issue to address with respect to indicators is the value-added of having aggregated indicators vs. many separate indicators. It was reasoned that this issue could be addressed in a simulation exercise.
- It was expressed that the system must be flexible enough to apply to a range of areas, issues, and components. A pilot site approach won't capture this range, although in response the group felt that a number of approaches could be tested at the pilot site, working in collaboration with managers.

- If this is a good direction to pursue, then the next step might be another workshop, focusing more closely on indicator frameworks, approaches, methodologies and the management interface. This would bring people together to propose areas for long term funding in this area.
- Management input is seen as critical to success.

Breakout Group 5 - Alternative Frameworks
Rapporteur: M. Pakenham

- The group had previously considered alternate EBM frameworks from an Ocean sector perspective. It stressed that indicators of this framework must serve the needs of not just scientists, but fish managers, senior management, the Minister, communities, NGOs, and so on. A wide spectrum of interests must be served.
- Given this, it felt that A clear understanding of DFO clients and their requirements is key to the department's future. This will help with acquiring resources, which will in turn give further moral support, and recognition.
- The group also pointed out that the most powerful indicators are those which resonate through a wide range of interests. Powerful indicators in turn will drive behaviour change, moving the ethic forward on stewardship and conservation. With this, the indicator program would be sustainable.
- This led to the essential need for transparent communication. The visual representation of info can motivate people. Data presentation should be dynamic, engaging, and visual, using the new media and the Internet. It should also be accessible and map-based, as this will aid in communicating with communities.
- Overall, the department needs to think more creatively about communicating information. The group recommended that there should be strategic planning regarding the development of key messages; i.e. marketing what the DFO does. This strategic planning should be a collaborative exercise.
- The presentation raised lively discussion. Concern was expressed that content may be eroded in favour of style and form. In response, it was felt that if scientists don't address the communications challenge; it would be done by people with even less interest in the content.

Managers' Perspectives on Group Presentations
Rapporteur: Simon Courtenay

A Habitat and Oceans Manager's Perspective (Jean Piuze)

Presentation Highlights:

- The speaker began by commenting on the day-to-day pressures on senior management, which gives them little time to attend workshops such as this. Added to this, he noted the complex circumstances under which managers operate (complex ecosystems, stakeholders more numerous than ever, government increasingly complex, etc.). These circumstances are evolving, as the DFO moves:
  - from fisheries single stock management to multi-species management.
  - from fisher-centred users to multiple users and uses (e.g., transportation, leisure, oil)

  - from "activity by activity" approaches to more collaboration and integrated management.
- Given this complexity, the overarching DFO goals should include both the promotion of harmony among users as well as the sustainability of ecosystems.
- What do managers need from scientists? While scientists must continue studying ecosystems, the information derived from this work can only be used by managers if it is translated appropriately and is attached to a management "toolbox". These tools need to be simple, workable, explainable, sellable, and efficient.
- One must also ask what do scientists need from managers? Managers must buy into the ecosystem approach, and they must inform scientists of user perspectives, how users interact with ecosystems, and identify allies/visionaries among users that see the need for EBM. Managers should be providing constant feedback to scientists, and help to seek funding for science to support EBM approaches.

Discussion:

- Participants wondered whether there exists a training program on EBM for DFO staff. In response, it was suggested that this workshop was laying the foundation for such training to begin. When it was suggested that the department may have to address the communication gap between scientists and managers, in response it was felt that communication could be improved but that everyone is generally on the same page.

An Ocean Manager's Perspective (Jack Mathias)

Presentation Highlights:

- The ecosystem approach is a new approach, intended to tie together DFO's work with that of other agencies, all of which should be working from the same framework. The speaker felt that this workshop was successful in bringing people together who are now talking 'the same language.'
- He also felt that the frameworks proposed might prove to be quite useful. He cautioned, however, that there was still no broader consensus on an ecosystem framework or objectives.
- He recommended that a broader consensus must be sought from scientists not attending the workshop. He recommended sending the workshop products to these groups for their comments and to encourage their buy-in.
- He reminded the participants that science must underpin EBM. Approaches such as IBI and TLA require further development, and added to this is the work of mapping human uses and ecosystem characteristics (done by Ian Perry).
- The EBM approach, he pointed out, will necessitate new roles for the department. The DFO should be taking a leadership role in EBM, but this role requires a defensible approach and in-house consensus (i.e. broad consensus among the sectors – fisheries, habitat and oceans).
- He reminded the group that Oceans brings a unique perspective in many ways, as it connects most readily to the global scale. Other sectors and departments must also buy into EBM.
- The speaker also noted the department's facilitation role in EBM. Operationalising the EBM framework can be achieved if it is comprehensiveness enough so that other agencies also fit within it, but the framework is not yet at that point.

- He mentioned Environment Canada's SOE reporting and the indicators they have developed, suggesting that the DFO look carefully at the work that has already been done.
- The EBM approach will also necessitate new processes for the department. He mentioned the need for broad consultation and collaboration with stakeholders, stressing again that, "EBM requires involvement and compliance by user groups who impact the ecosystem." It is explicitly recognised in the *Oceans Act* that governance must be shared with clients. Consultation requires grabbing people's attention, being clear and understandable, and sustaining people's interest (by striking human incentive systems). Collaboration requires a degree of co-management, a re-thinking of institutional structures and mechanisms to facilitate interaction with stakeholders (stewardship), empowerment (awareness raising, extension), and public education.
- The speaker concluded by pointing to objectives such as developing and implementing integrated management plans, and addressing multiple use conflicts.

Discussion:

- Most participants agreed that the message scientists give needn't be "simple", but rather has to be clear and understandable. It is important not to oversimplify, as the management of our oceans is by no means simple.

Closing Comments (Bob O'Boyle and Glen Jamieson)

The workshop co-chairs briefly reviewed the progress made during the workshop. They noted that the participants had comprehensively considered the objectives of the National Policy Committee and had responded with another set of "high level" objectives embedded in a newly proposed EBM Framework. Along with the objectives, the workshop had been successful in developing a set of objectives, characteristics and indicators, which further clarify the intent of the higher level, conceptual, objectives. The workshop had also discussed promising methods, which would allow monitoring of progress towards the objectives. Finally, the workshop had brought together a diverse group of scientists, managers, policymakers, and regions to discuss the highly complex issue of ecosystem-based management. During the discussion, old definitions had been clarified and new ones added. It was emphasized that the workshop was the beginning of a process and that we had set out to 'hit the board', not the 'bull's eye'. Overall, the workshop had achieved its stated objective and had improved awareness of ecosystem-based management in the department.

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AFSC – Alaska Fisheries Science Center, Seattle, Washington
BIO – Bedford Institute of Oceanography, Dartmouth, Nova Scotia
CSIRO – Commonwealth Scientific and Industrial Research Organization
ELA – Experimental Lakes Area, Winnipeg, Manitoba
FISL – Freshwater Institute Science Laboratory, Winnipeg, Manitoba
GFS – Gulf Fisheries Centre, Moncton, New Brunswick
GLLFAS – Great Lakes Laboratory for Fishery and Aquatic Sciences
IOS – Institute of Ocean Sciences, Sidney, British Columbia
MLI – Maurice Lamontagne Institute, Mont-Joli, Quebec
NAFC – Northwest Atlantic Fisheries Centre White Hills, St. John's, Newfoundland
NHQ – National Headquarters, Ottawa, Ontario
NOAA – National Oceanic and Atmospheric Administration
PBS – Pacific Biological Station, Nanaimo, British Columbia
SABS – St. Andrews Biological Station, St. Andrews, Nova Scotia
WSFRI – West Sea Fisheries Research Institute, Inchon, Korea
WVL – West Vancouver Laboratory, West Vancouver, British Columbia

APPENDIX 6: PRESENTER BIOGRAPHIES

John T. Anderson

Dr. Anderson has been a Research Scientist with the Department since 1979. He received his B.Sc. in Marine Biology from the University of Guelph in 1973, his MSc. in Biological Oceanography from the University of Guelph in 1978, and his Ph.D. in Fisheries Oceanography from the University of British Columbia in 1992. Since joining the Department, Dr. Anderson has been involved with various aspects of Fisheries Oceanography and Fisheries Ecology, studying the dynamics of early life stages of fish especially the ecology of juvenile Atlantic cod and capelin. Dr. Anderson has been Section Head of the Fisheries Ecology Section since 1991. As an Adjunct Professor, Ocean Sciences Centre, Memorial University of Newfoundland, Dr. Anderson maintains an active research program within the university community.

Joe Arbour

Joe Arbour is Manager of the Oceans and Coastal Management Division (OCMD), Oceans and Environment Branch, Maritimes region. This division is responsible for the implementation of programs under the oceans act relating to Oceans and Coastal Management including Integrated Management, Marine Protected Areas and Marine Environmental Quality. Dr. Arbour recently moved to DFO after 24 years at Environment Canada in the Ontario and Atlantic Regions. Dr. Arbour holds a Ph.D. in Agricultural Engineering from the technical University of Nova Scotia, with a focus on non-point source pollution from agriculture.

Andrew J. Constable

Andrew has been involved in the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) since 1986, joining its Working Group on Fish Stock Assessment in 1989 and contributing to the Working Group on CCAMLR Ecosystem Monitoring Program from 1991 and joining the Working Group on Ecosystem Monitoring and Management in 1998. Andrew's training is in experimental marine ecology, with an emphasis on the application of science in the management of marine resources in Australia. Andrew spent six years as an academic teaching marine ecology and management before joining the Australian Antarctic Division in 1997. Publications have ranged widely, including life histories in sea urchins, monitoring of seals, utility of science in management, population dynamics of fish stocks, Antarctic ecosystem modeling and specialist software for undertaking

Robert Gregory

Dr. Gregory has a B.Sc. (Acadia - 1980), a MSc (Trent - 1983), and a Ph.D. (UBC – 1991), specializing on the habitat use and ecology of larval and juvenile marine and freshwater fishes. He was a Postdoctoral Fellow at West Vancouver Laboratory (DFO) and a Research Associate at Memorial University of Newfoundland. Since 2000, he has been a Research Scientist with DFO, at the Northwest Atlantic Fisheries Centre, St. John's, where he is building a research program on habitat productive capacity. He is also an Adjunct Professor of Biology at Memorial University. Bob has led several research programs on juvenile fish-habitat associations and habitat and age-specific abundance, mortality, and growth. In the past six years, much of that work has been on age 0 Atlantic cod. His interests in spatial and temporal scale dependant processes have emerged from observations in the field and laboratory working on scales ranging from 10s of centimeters to 1000s of kilometers, and from behaviours measured at less than a second to recruitment patterns manifested over decades.

Glen Jamieson

Dr. Glen Jamieson has been a research scientist for 22 years with the Department of Fisheries and Oceans. He spent five years in the Maritime Provinces and the past 17 years in British Columbia. While at the Pacific Biological Station, Nanaimo, he headed the invertebrate stock assessment program from 1981 to 1993. He is now involved with marine ecosystem and protected area research, is a member of the inter-agency Pacific Marine Protected Area Working Group, and is currently working on an ecosystem overview of the Gabriola Pass pilot MPA. Dr. Jamieson obtained his B.Sc. at McGill University in 1967, and his MSc and Ph.D. at the University of British Columbia in 1970 and 1973, respectively. He has published extensively on exploited invertebrate species, is an author of DFO's Shorekeeper's Guide, and is investigating the introduction and impacts of exotic marine species in BC. He has previously organized and been senior editor on two North Pacific Invertebrate Stock Assessment and Management Symposia (Can. Spec. Publ. Fish. Aquat. Sci. 92 and 125, 1986 and 1998, respectively), and produced a summary of exploited marine invertebrates of BC (Can. Spec. Publ. Fish. Aquat. Sci. 91, 1986). Dr. Jamieson has been on the Editorial Board of the Canadian Journal of Fisheries and Aquatic Sciences since 1993.

Ellen Kenchington

Dr. Ellen Kenchington is a Benthic Ecologist/ Molecular Geneticist at the Bedford Institute of Oceanography with Fisheries and Oceans Canada. Dr Kenchington obtained her degrees from Dalhousie University (B.Sc., M.Sc.), and the University of Tasmania (Ph.D.). Her current research areas include a three-year otter trawling experiment conducted on a deep-water (120-146 m) sandy bottom ecosystem on the Grand Banks of Newfoundland that had not experienced trawling since at least 1980. A similar experiment is now in progress on a rocky bottom site (70 m) on Western Bank where the benthos is sampled with grabs and also using cameras. Fisheries research on scallops in the Bay of Fundy includes stock assessments, and recently analysis of scallop bycatch (303 taxa identified to date) Genetic research on commercial fish and shellfish is done in collaboration with the Marine Gene Probe Lab at Dalhousie University. Current projects include investigations into sex determination in mussels and genetic structure of lobster and scallop.

Greg Klassen

Dr. Klassen, a recent addition to the Centre for Coastal Studies and Aquaculture at UNBSJ, studies the evolutionary and ecological interactions among ecologically associated lineages of aquatic animal. In particular, he focuses on the coevolutionary relationships between fishes and their parasite faunas. Dr. Klassen uses his research to study small and large scale issues relating to climate change, biodiversity and conservation biology. He is currently engaged in developing two model systems.

On a Global scale, Dr. Klassen is involved in an international effort (including researchers from Canada, the United States, Costa Rica, Mexico, France, England and Australia) to develop a Global data-base on the biodiversity and coevolutionary relationships of sensitive coral reef fishes and their parasite communities. He is also collaborating on a global project supported by DIVERSITAS on the biodiversity of parasites from sticklebacks. One aspect of this work relates to the utility of using parasite faunas as indicators of climate change.

On a local scale, Dr. Klassen is heading a long-term project at Kouchibouguac National Park on New Brunswick's Southern Gulf Coast. This project involved the development of a long-term monitoring program for Southern Gulf Coast estuaries based on an ecosystem-level approach to conservation. The project follows the IBI (Index of Biotic Integrity) model developed along the eastern Atlantic Coast of the US. Ultimately, it is anticipated that this program – funded by Parks Canada – will be used for monitoring of the health of estuarine ecosystems all along the Southern Gulf of Saint Lawrence coastline.

Dr. Klassen is actively involved in numerous international societies (including the Society for Systematic Biology, American Society of Parasitologist, American Society of Ichthyologists and Herpetologists, Estuarine Research Federation) and is co-founder of the newly established Gulf of Saint Lawrence Estuarine Research Society (GSLERS). Dr. Klassen actively involves students at all levels in his research. He is presently co-supervising one Ph.D. student (University of Perpignan, France), supervising two MSc students and several Undergraduate students at UNBSJ.

Colin Levings

Dr. Colin Levings is head of the Coastal and Marine Habitat Science Section and also is project leader for several research programs. In 1997, he initiated a major field and lab project focusing on the impact of acid mine drainage from Britannia Mines, Howe Sound, on nearshore salmon habitat. Dr. Levings and John Pringle organized a regional workshop on ecosystem delineation in the Strait of Georgia, in support of the Oceans Act. The objective was to reach consensus on ecosystem boundaries, at a variety of scales, to assist with ICZM. Dr. Levings is doing this work with a comparison of yields from D.F.O. statistical areas and the ecosystems described in the 1997 workshop. Dr. Levings is also frequently called upon for advice by D.F.O. habitat and ocean managers on coastal ecology topics ranging from log storage impacts on the north coast to polychaete dieoffs at the Squamish estuary, to estuary restoration evaluation at Campbell River. In support of the ocean and habitat managers of FOC, applied ecology on nearshore habitats of the northeast Pacific, ecosystem delineation in the coastal zone, and estuarine ecology of juvenile salmon. Dr. Levings has degrees in Fisheries and Zoology from U.B.C. and in Biological Oceanography from Dalhousie. He has been working on applied fish habitat research in coastal British Columbia since 1972, especially in estuaries, in support of habitat managers. He also worked on this topic in Nova Scotia, Norway, Korea, and Japan.

Patricia A. Livingston

Patricia Livingston has been a fishery research biologist at the U.S. National Marine Fisheries Service (NMFS) – Alaska Fisheries Science Center in Seattle, WA, since 1977. She received her B.Sc. in Fisheries from the Michigan State University, M.Sc. in Quantitative Fisheries Management and M.P.A. in Natural Resource Administration and Policy from the University of Washington. Pat is presently serving as leader of the Resource Ecology and Ecosystem Modeling Program. At NMFS she has worked to parameterize, debug, and test various ecosystem and upper-trophic level models of the N. Pacific. Her research has focused on understanding groundfish trophic interactions relative to marine birds and mammals, particularly in the eastern Bering Sea. The work of her group over the last decade has been to build a database documenting groundfish food habits and to provide important information for understanding groundfish feeding ecology, marine food webs and parameterizing upper-trophic level models of predation and bioenergetics of groundfish populations. Pat is deeply involved in PICES activities, at first as a member of the WG 5 on Bering Sea and a member of Model Task Team for the PICES-GLOBEC Climate Change and Carrying Capacity (CCCC) Program and since 1996 as Co-chairman of the Implementation Panel of the CCCC Program. At PICES VII she was elected the new Chairman of Science Board.

C. Ken Minns

Dr. Ken Minns joined DFO in 1974 after completing his Ph.D. on population bioenergetics and simulation modeling under the tutelage of Jyri Paloheimo with a short interlude as an arctic limnologist guided by Frank Rigler. Ken was recruited by Murray Johnson as the Great Lakes laboratory flourished in the 1970s and 1980s. He has worked in teams on a succession of areas including eutrophication, pulp and paper mill effluents, acidic deposition with a special focus on modeling, fish community dynamics, and larger scale integrated assessment. In recent years his main focus has been the development of habitat assessment tools in freshwater for use by habitat managers in support of the fisheries act and the habitat policy. He has also been a keen explorer of the potential and applications of GIS for fish and habitat management. Most recently he has renewed activity in productivity modeling seeking to link his habitat and fish production interests for improved ecosystem management.

Robert Mohn

Robert Mohn received his Bachelor's and a Master in Physics, followed by a Masters in Mathematics. His Doctorate was in human physiology and did post-doctoral work estimation of the electrical activity of the heart, given the body surface measurements. Mohn joined DFO in 1977 and initial worked modeling grey seals. Since then he has worked on the modeling of finfish, invertebrate and marine mammal populations. His other field of research is the development and application of resource assessment and management methods. Most recently, research has been focussed on developing a six species ecosystem model of the Scotian Shelf to explore the effects of model uncertainty in stock assessment. Also, he is working with a team to develop an operational 'Traffic Light' system for resource assessment.

Jean Munro

Jean Munro obtained his M. Sc. from Laval University in Quebec City in 1975, on the ecology and behaviour of the Common eider in the St. Lawrence estuary. In 1978 Jean was appointed as marine ecologist in the DFO Science team in the new Quebec Region. Initial projects dealt with the Magdalen Islands lagoon ecosystem, especially macrobenthic communities and lobster populations. Later in 1983, Jean concentrated on migrations, spawning sites and larval development of Atlantic herring in the St. Lawrence estuary. When the Maurice-Lamontagne Institute was completed in 1988, with new aquaculture experimental facilities and ecophysiology team, Jean joined in to work on the physiological limits and condition indicators of Atlantic cod, American plaice and Snow crab. From 1996, the previous experiences on benthos and fish ecology and physiology were applied to impact assessment studies within the Habitat Science section. Three successive studies examined sediment impacts on the coastal, fjord and estuarine benthic habitats, the last and current one involving Atlantic sturgeon habitat in the upper St. Lawrence estuary. Following a recent appointment as chief of Habitat Science (1998), Jean is also working at developing and applying the marine ecosystem health concept to the coastal benthic communities of the estuary and gulf of St. Lawrence.

J. Lobo Orensanz

Jose (Lobo) Orensanz trained first as a zoologist and his early years of academic life were devoted to the study of the marine invertebrate fauna, mostly polychaete worms, of the southwestern Atlantic. Later he became involved with the assessment and management of small artisanal fisheries targeting benthic stocks. In 1977 he was forced to leave his country during the last military regime. He moved to the United States and pursued a second doctoral degree at the University of Washington School of Fisheries. While studying and later working as a research scientist and lecturer at UW, he became active with the conservation and management of benthic fisheries in the Pacific Northwest region. Over the years in the U.S., Lobo maintained ties to South America and developed an active network of colleagues focusing on benthic fisheries in the southern region of the continent. He participated in the implementation of territorial fishing rights of Chilean benthic fisheries and in conservation issues of the benthic fisheries in Argentine Patagonia. In April 2000, 22 years after politically forced exile from his homeland, Lobo returned to Argentina as research scientist at CONICET--the Argentine Council for Science & Technology. That year he was selected as a Pew Fellow in Marine Conservation. Much of his efforts now pertain to the use of scientific knowledge in the interaction between fishers, scientists, and managers to improve marine management systems in Argentina and other South American countries.

Ian Perry

Ian Perry is a fisheries oceanographer working at the Pacific Biological Station of Fisheries & Oceans Canada, in Nanaimo, BC. Prior to this posting, he worked for Fisheries & Oceans at the Biological Station in St. Andrews, N.B. His general area of research is the study of how global changes impact the structure and functioning of marine ecosystems. He examines how environmental and anthropogenic variability influence the distributions and recruitment of marine finfish and invertebrate populations. Additional interests include developing ecosystem-based approaches to the assessment and management of marine systems, and developing methods to provide scientific advice for the management of new and developing (i.e. data-poor) fisheries. Among other science-community activities, he is presently vice-Chair of the Global Oceans Ecosystem Dynamics (GLOBEC) core project of the International Geosphere-Biosphere Program.

Jake Rice

- B. Sc. in Conservation (Biology) from Cornell University (1970), Ph.D. in Ornithology (Zoology) from University of Toronto (1974). Post Doctoral Fellow in Psychology at U of T (1974-75).

- Professorial positions in Biology, Math-Stats, and/or Environmental Studies at Memorial University (full time 1976-1981), Arizona State University (part time 1977-1980, full time 1980-1982) and University of Copenhagen (visiting scholar - Royal Danish Academy 1996).
- Worked for DFO - Science in Newfoundland Region (Section Head - Fisheries Ecology & Division Head - Groundfish 1982-1990), Pacific Region (Division Head - Marine Fish, and Chair - PSARC, 1990-1996), and Headquarters (Coordinator CSAS - 1997-present)
- Research Foci -
  - Community structure and dynamics, including role of environmental forcing and exploitation (bird communities in Ontario and Arizona, seabirds in Newfoundland, and marine fish & invertebrates in the Northwest Atlantic, North Sea, and Baltic Sea), and theoretical approaches to ecosystems and communities
  - Analytical tools for inclusion of uncertainty in fisheries assessments and advice (Stock - recruit forecasting; survey biomass estimates etc).
  - Information content of metrics of community status and ecosystem effects of fishing.
  - Precautionary Approach and processes for setting management objectives.
  - Criteria for categorizing marine species by risk of extinction.
- Key recent committees & tasks
  - Canadian member - ICES Advisory Committee on Fisheries Management
  - Invited expert - ICES Advisory Committee on the Marine Environment and ICES Advisory Committee on Ecosystems
  - Member - NOAA Science Advisory Board
  - ICES Working Group on Ecosystem Effects of Fishing (chair 1996-present)
  - ICES Multispecies Assessment Working Group (Chair 1990-1995)
  - Review Panel of NOAA Coastal Sciences Center, Beaufort, SC (Panel Chair 2001)
  - FAO - CITES Technical Consultations on Applicability of Criteria for Listing Marine Species (Contracted Expert 1999-2000)
  - Co-chaired Recent ICES Mini-Symposia or Theme Sessions on Ecosystem Effects of Fishing (1996), Ecosystem Management, Can it be Made Operational (1999), ICES Role in Conservation of Biodiversity (2000), and Information Content of Metrics of Ecosystem Status (2001)
- Publications:
  - Over 50 publication in primary journals, including *Ecology, Ecological Monographs, Canadian Journal of Fisheries and Marine Science, ICES Journal of Marine Science, Theoretical Population Biology, Behaviour, Animal Behavior, Journal of Marine Sciences, North American Journal of Fisheries Management, etc.*

John Shearer

John Shearer is currently Senior Biologist and Operations Manager of the Experimental Lakes Area (ELA), a special, ecosystem research facility operated by DFO in the Boreal Shield of northwestern Ontario. Based at the Freshwater Institute in Winnipeg, John also serves as Chair of the ELA Management Board, a federal-provincial body which oversees ELA operations. The ELA has gained an international reputation for experimental research and monitoring on small lake ecosystems. John has been associated with the ELA since 1969, and was primarily involved in the estimation of algal photosynthesis (primary production) for much of that time.

Brian Smiley

Brian is a marine research biologist employed in the Marine Environment and Habitat Science Division, DFO Science Branch at the Institute of the Ocean Sciences. He has coordinated the Pacific Region's scientific contributions to state of the environment reports, indicator factsheets and environmental trend web pages over the past 15 years. He has coordinated the cataloguing of 4,700 historical datasets for the Canadian Arctic and Pacific including the appraisal of their 1,300 measurement types. Brian is presently coordinating the Division's citizen science initiatives for intertidal and subtidal monitoring in British Columbia called Shorekeepers and Reefkeepers respectively.

Tony Smith

Tony Smith completed his Ph.D., in adaptive fisheries management, at the University of British Columbia in 1979. He then spent ten years working in epidemiology, entomology, and soil science, in the UK and Australia. Tony joined CSIRO Marine Research in Hobart in 1989, where he worked initially on stock assessment of orange roughy. He spent several years developing stock assessment methods including Bayesian methods, and also developing an approach to resource assessment and management called "management strategy evaluation" (MSE). This approach allows evaluation of whole adaptive management systems, including monitoring, assessment and decision rules (also called feedback harvest strategies or management procedures). He has applied these methods to a wide range of fishery resources both within Australia (orange roughy, gemfish, tunas, rock lobster, prawns, abalone) and also reviewed assessment approaches in the US, South Africa, New Zealand and Namibia. He also played a major role in the design and development of a large-scale adaptive management experiment on the Great Barrier Reef. Lately, he has been extending the MSE approach to design and evaluation of regional management plans for multiple use of the marine environment, with a major application on the North West Shelf of Australia. He is also currently undertaking research on robust indicators for monitoring the ecological impacts of fishing on by-catch species, habitats and marine food chains.

Herb Vandermeulen

Herb Vandermeulen obtained his Ph.D. from the University of British Columbia, specializing in aquatic macrophyte ecology. He has worked as a research scientist abroad and in Canada. Herb has published studies on acid lakes, algal taxonomy, water quality in reservoirs, contaminants, data acquisition, hypolimnetic aeration, freshwater and marine macrophyte ecology, marine indicators development, monitoring marine ecosystem health, introduced species, and aquaculture. He was the senior marine specialist for Environment Canada's State of the Environment program. Herb is presently employed by DFO as the National Coordinator - Marine Environmental Quality.

APPENDIX 7. GLOSSARY OF TERMS

Glossary of Ecological Terms used in the Oceans Act and its Implementation Programs (draft February 2000)

Marine environmental quality: "is an overall expression of the structure and function of the marine ecosystem taking into account the biological community and natural physiographic, geographic and climatic factors as well as physical and chemical conditions including those resulting from human activities." (Skjoldal, 1999)

Marine environmental quality indicator: A measure (physical, chemical or biological) or parameter that provides evidence as to the condition or state of specific components of the ecosystem.

Marine environmental quality objective: A numerical value or narrative statement describing a desired condition for a given ecosystem, taking into account ecological characteristics and uses.

Marine environmental quality guidelines: Generic numerical values or narrative statements that are recommended as upper or lower limits to protect and maintain healthy marine ecosystems. These values are not legally binding.

Marine environmental quality standards: A legally enforceable numerical limit or narrative statement, such as in a regulation, statue, contract, or legally binding document, that has been adopted from a criterion or an objective.

Marine environmental quality criteria: A numerical value or narrative statement for physical, chemical or biological characteristics of water, biota, soil, or sediment that must be respected to protect and maintain healthy marine ecosystems.

Objectives, Indicators and Reference Points (this workshop)

Conceptual or **qualitative objectives:** General statements about the state of the ecosystem which are uniformly accepted by all stakeholders as desirable. They are specific enough that everyone will interpret them the same way, but do not specify how they will be measured.

Operational Objective: Objective that has a direct and practical interpretation in the context of (fisheries) management and against which performance can be evaluated quantitatively

Characteristic: Biological property of the ecosystem, separate from our measurement of it. For instance, recruitment is a characteristic of a fish population. Survey age one numbers per tow or age number numbers from a population analysis might be the associated indicators.

Indicator: Quantity that can be measured and used to track changes over time with respect to an operational objective

Performance Measure: Function that converts the value of an indicator to a quantitative measure of management performance with respect to the operational objective (usually be comparing the indicator to a reference level or point)

Reference Point: Value of an indicator corresponding to a management target or threshold
Note: the operational objective, indicator, performance measure and reference point form a package. Each of the three elements of the package is essential to properly define and interpret an indicator.

APPENDIX 8. ACRONYMS

Acronym	Definition
CAR	Communities at Risk
CCAMLR	Convention for the Conservation of Antarctic Marine Living Resources
CCLCRMP	Central Coast Land Coast Resource Management Plan
CEMP	CCAMLR Ecosystem Monitoring Program
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CSAS	Canadian Science Advisory Secretariat
CSI	Composite Standardised Index
DFO	Fisheries and Oceans Canada
DOC	Dissolved organic carbon
DOE	Environment Canada
EBM	Ecosystem-based Management
ELA	Experimental Lakes Area
ESSIM	Eastern Scotian Shelf Integrated Management
ESSRF	Environmental Science Strategic Research Fund
ESU	Ecologically Significant Units
EU	European Union
FIB Index	Fishery is Balanced, EcoPath indicator
GLOBEC	Global Ocean Ecosystems Dynamics
HACCP	Hazard Analysis Critical Control Point
IBI	Index of Biological Integrity
ICES	International Council for the Exploration of the Sea
IFMP	Integrated Fisheries Management Plan
IM	Integrated Management
KNP	Kouchibouguac National Park
LME	Large Marine Ecosystem
LTOP	Long term observational programs
MEQ	Marine Environmental Quality
MEH	Marine Environmental Health
MPA	Marine Protected Area
MSVPA	multi-species virtual population analysis
N	Population Size
N_c	Census Population Size
N_e	Effective Population Size
NAFO	Northwest Atlantic Fisheries Organization
NMFS	National Marine Fisheries Service
NPC	National Policy Committee
NPFMC	North Pacific Fishery Management Council
OMA	Ocean Management Area
PA	Precautionary Approach
PAR	Populations at Risk
RP	Reference Point

Acronym	Definition
R:P	Respiration to production
RAP	Regional Advisory Process
SAR	Species at Risk
SARA	Species at Risk Act
SOE	State of the Environment
SPA	Sequential population Analysis
SSB	Spawning Stock Biomass
SSM	Single Species Management
TAC	Total Allowable Catch
TEK	Traditional Ecological Knowledge
VEC	Valued Ecosystem Component
WGEO	Working Group on Ecosystem Objectives